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PROTECTION OF WORKERS FROM PESTICIDE EXPOSURE *

by

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Workers are often subjected to relatively high levels of pesticide compounds when actively engaged in pest control operations or working directly with the compounds in formulating or manufacturing plants. Illnesses resulting from overexposure to pesticide chemicals do occur among such workers. Most, however, are a result of carelessness or accident. Experience has shown that if proper precautionary measures and directions are followed even the more toxic compounds can be used safely.

Even though there is an effort to insure that all pesticides produced in the future will be low in toxicity to warm-blooded animals and not persistent in the environment, any great change in this direction will probably not take place in a very short period of time. Thus, at least in the immediate future, we can expect to see continued use of compounds that are relatively toxic to warm-blooded animals. In fact, several of the new compounds that have reached the point of registration during the last couple of years have acute oral LD_{50} values of less than 50, which indicates that they are highly toxic. Also, we have no firm assurance that less persistent compounds developed within the next few years as replacements for persistent pesticides now being used will be of low mammalian toxicity. Thus, we should not lessen our concern about the acute hazard to persons who come in contact with such compounds. Protection of such persons from exposure is necessary if a good record for safe use and handling of pesticides is to be maintained.

Much of the safety in relation to pesticides rests on the user or applicator of the compounds. If he is knowledgeable concerning pesticides and understands the importance of taking proper precautions he can do much to insure the safety of himself and others. This also applies to workers involved in the manufacture and formulation of toxic compounds. Their contact is usually with the more concentrated forms of pesticides; therefore, they should be especially aware of the need for protecting themselves from exposure. Thus, an important adjunct to safety in relation to pesticides is education, not only of supervisory personnel but also of those individuals who actually handle the materials.

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There are several very important indirect ways of protecting the worker such as providing education and medical supervision, stressing the importance of personal hygiene and cleanliness, the importance of not being careless, and pointing out the need for reading and following directions on the pesticide label. However, these topics will be covered by other presentations on this program. The main purpose of this presentation is to discuss the more direct protection of the various routes of entry of pesticide into the body. Protection of these routes means prevention of exposure and prevention of exposure is undoubtedly the best insurance against poisoning.

ROUTES OF ENTRY

There are four routes of entry of pesticide compounds into the body: (1) dermal, (2) respiratory, (3) oral, and (4) through cuts or abrasions in the skin.

DERMAL ROUTE

The dermal route is considered to be the most important route of entry into the body during most exposure situations in the field and probably plays an important part in exposure of workers in formulating plants. This route is one that has undoubtedly been responsible for a great many poisonings of workers, especially from the more toxic organophosphorus compounds.

In research studies we have measured the potential exposure of several hundred pesticide applicators, and the results indicate that over 97% of the pesticide to which the body is subjected during most exposure situations, and especially to applicators of liquid sprays, is deposited on the skin. It should be understood that any given amount of pesticide is more rapidly and more completely absorbed by the oral or respiratory routes. However, absorption of pesticides by these two routes is probably too small a fraction of the total potential exposure to be considered the main factor in most poisoning cases of workers in the field.

In one set of experiments, for example, we have calculated the potential dermal exposure of orchard spraymen to parathion to be approximately 19 mg/hr; however, the potential respiratory exposure was calculated to be only 0.02 mg/hr of exposure.[6] This indicates that there is potentially 950 times more dermal exposure than respiratory exposure to workers in that type of application operation. Thus, if only a small fraction of the potential dermal

exposure was to be completely absorbed it would probably still be more than the respiratory exposure. The respiratory route, however, takes on increased importance when exposure is to vapors, fine dusts, fogs, or aerosols made up of very small droplets.

The importance of protecting specific body areas has not been clearly defined in the past. This is because the rate of absorption of different compounds through human skin is difficult to measure with any degree of accuracy. The most useful and probably most accurate estimations or measurements on the percutaneous penetration of pesticides in man which have been accomplished thus far have been made by Maibach and Feldman.[1] Using radioactive labeled pesticides they were able to determine approximately what fraction of an applied dose would be absorbed through the skin. In this way they not only compared the degree of dermal absorption for certain pesticides but also compared absorption of a single pesticide for different parts of the human body. The results obtained indicate that sufficient importance may not have been attached to protection of certain body areas.

Lower Trunk and Legs.--In checking dermal penetration of parathion at different body areas these researchers found that the area of greatest absorption on man is the scrotum where approximately 100% of an applied dose was absorbed. The possibility of pesticide on this body area being completely absorbed is a very important point and emphasizes the need for increased concern about protection of the area. Of utmost importance would be the need for extreme caution in order to avoid spillage of highly toxic liquid pesticide onto the scrotum.

Although cloth coveralls or trousers provide a reasonable amount of protection where contamination does not easily penetrate clothing, the wearing of waterproof trousers provides the best protection for the lower trunk and leg areas and is especially recommended in work situations where there is chance of liquid spillage, soaking by continued contact with more dilute liquid sprays, or penetration of clothing through excessive contact with dry pesticides. In formulating plants where the main outer protective garment is usually cotton coveralls, workers should be required to wear waterproof aprons, especially if they are on duty at bagging or mixing stations where there is often considerable contamination down the front of the clothing with relatively concentrated wettable powder formulations. Fortunately, many plants require the use of aprons. Even when the waterproof apron is used it is very

important that the worker change to freshly laundered clothing each day in order to prevent contamination of the scrotum or other skin areas. Needless to say, use of clean clothing and daily bathing in an effort to avoid excess dermal absorption are essential in any type of exposure situation.

Upper Trunk and Arms.--Protection of the upper trunk and arms from contamination by toxic pesticides is important, especially under conditions where heavy spray drift may thoroughly wet cloth shirts, coveralls, and underclothing or where concentrated dry pesticides come in contact with clothing and skin in formulating plants. Our studies have shown that the greatest potential contamination of spraymen in this general body area is the upper back, shoulders, and forearms of workers operating equipment which propels spray up into the air where it is more subject to drift. Under these conditions a waterproof jacket or raincoat provides the best protection for this general body area. This gear is usually worn during cooler conditions, but as the temperature rises and the clothing becomes unbearably hot to wear, workers tend to discard them and work with much less protection--perhaps only a short-sleeved T-shirt-type undershirt on the upper trunk area. Under such conditions workers should be encouraged to at least wear a long-sleeved cloth jacket that will not be easily penetrated by pesticide, and preferably one that can be properly washed.

The wearing of long-sleeved heavy grade "GI" cotton shirts or coveralls as outer clothing during hot weather, often with no underclothing, is popular with many applicators even though this is not a recommended practice. Fortunately, these items of outer clothing provide a reasonable amount of protection where spray drift is light with very fine droplets that do not wet through to the skin. Under such conditions the clothing should be changed and laundered daily. If clothing used during spraying such as shirts, jackets, or coveralls are merely hung up to dry after work and used repeatedly, as is often the practice, it doesn't take long for the pesticide material to work through where it will make contact with underclothes or skin.

In selecting protective clothing for workers it is important to take into consideration the comfort of the individual when he wears such items. The conventional black or dark green rubberized or plastic waterproof jackets in common use during past years are considered by many applicators to be uncomfortable to wear not only because of greater heat absorption but also because they may be of heavy grade material and not very flexible.

During recent years, however, several jackets and jacket-trouser combinations that are lighter in color and weight have been available. Although less durable, they are less costly to replace. Our tests have shown that a light yellow or white waterproof jacket may reflect enough heat to cause the temperature at the skin surface to be as much as 8 to 10°F lower than when wearing a black jacket under certain conditions of intense sunlight when ambient temperature is approximately 90°F. Nevertheless, there is still considerable discomfort in wearing any waterproof clothing during hot weather because of the trapping of body heat.

Disposable paper jackets have been tested and found suitable for use only under conditions where heavy wetting does not occur. Such paper jackets were found to be much cooler and thus more comfortable than other jackets tested.

Observations of pesticide applicators have indicated that although waterproof clothing items, and especially jackets, are usually carried by the workers, or readily available to him, he usually will not don the clothing until drift of pesticide increases to the point where he feels protection is necessary. Unfortunately, by this time there is often considerable contamination of skin and clothing. The covering of contaminated skin areas by waterproof clothing may create conditions under which dermal absorption may be increased. This may be more important during hot weather where high temperatures and perspiration are involved. Whether or not there would be less absorption under these conditions than if the clothing were left off entirely depends upon the potential exposure which might occur after the worker puts on the clothing. Maibach and Feldman[1] found that covering up (occlusion) of contaminated skin with thin plastic wrap material caused approximately a four-fold increase in absorption of parathion. Although the increase of absorption of pesticide by covering contaminated skin with various items of protective clothing is not known, the above occlusion test results are cause to emphasize the need to put on protective gear before the skin has been contaminated to any great degree.

The use of waterproof jackets in pesticide formulating plants is not common and generally not considered a requirement if, as stated earlier, rubber aprons are worn and coveralls are kept clean. It should be noted, however, that in a plant there is easier immediate access to showers and other means of decontamination, should excess exposure occur, than in the field where applicators work.

Head-Neck Area.--Results of the dermal absorption studies noted above indicate that the head-neck area should be given more attention. In this area absorption of parathion was found to be from 32 to 47% of an applied dose;[1] much more than we would have anticipated and more than at other areas of the body studied with the exception of the armpit and scrotum. When observing either pesticide applicators or workers in formulating plants it is easy to conclude that the face-neck area is less protected than most other parts of the body. Head coverings or caps used in formulating plants are often made of material that allows easy penetration of pesticide onto the scalp. The headgear may have no bill or brim which would provide some added protection to the face-neck area, especially from pesticide material which drifts downward.

Protection from downward drift is especially important during application of liquid sprays. The headgear most commonly used by pesticide applicators is the billed cap which provides some protection for the face but very little for the remainder of the head-neck area other than the scalp. The conventional "Sou'wester" rain hat, often used when heavy downward drift occurs, does not provide exceptionally good protection for the face and sides of the neck. This is because of the narrow brim in all areas except at the back of the neck. Metal or fiber "hard hats" are also used to some extent; however, most have too narrow a brim to provide adequate protection. "Hard hats" which allow circulation of air over the head under the hat should not be used where exposure is to toxic dusts.

Our studies have shown that the greatest protection from downward drift of pesticides is afforded by some type of wide-brimmed hat, preferably made of water-repellent material. Waterproof hats, other than the "Sou'wester," were not readily available at that time. However, one is now available which is waterproof and also has a wide brim that affords good protection of the face-neck area. This type of hat should be recommended for use by all applicators who may be subjected to downward drift of pesticides.

Of particular interest in relation to exposure of the head-neck area is the finding by Maibach and Feldman[1] that absorption of parathion is relatively efficient (47% of applied dose) in the ear canal. Exposure in this area could occur through drift of fine pesticide mists or dusts or by digging in the ear with the tip of a contaminated finger. Of particular importance is the potential for drift into the ear of concentrated dry formulations of toxic compounds in the formulating plant.

It is of importance to note that wearing goggles and respirators provides considerable protection to the face.

Although a statement suggesting the use of goggles can be found on certain pesticide labels, they are rarely worn except by pilots who apply pesticides by aircraft. Questioning of pilots has revealed that they wear goggles not only to prevent poisoning and to keep wind out of the eyes but also to prevent certain organophosphorus pesticides that are direct inhibitors of cholinesterase from causing miosis. This is understandable because it has been shown that unilateral contamination of the eye with TEPP may cause pilots to inadequately judge distance.[4] The incoordination which may accompany this could be a serious threat to safety.

Hands.--The hands are often the body area having the highest exposure to pesticides and they have a greater chance of coming in contact with the more concentrate formulations. They are also more subject to cuts or abrasions, which will be discussed later.

High potential exposure to the hands brings attention to the need for wearing gloves. Some people who have worked with pesticides feel it is better not to wear gloves than to wear gloves that are contaminated on the inside; something which invariably occurs to some degree. Our research concerning the use of protective gloves indicates that, unless there is gross contamination of the inside of the gloves, the potential exposure is less when wearing gloves than when not wearing them. If gloves are kept clean on the inside there is very little doubt concerning the value of their use when handling pesticides. Unlined rubber gauntlet gloves provide the best protection because the gauntlet covers the wrist area not normally covered by the jacket sleeve and they can be turned wrong side out for proper cleansing of the unlined inside surface.

Feet.--Waterproof shoes or boots should be worn when handling or applying pesticides on a large scale. During liquid spray operations the ground cover of weeds, grasses, or other plants invariably becomes wet with dilute pesticide regardless of whether or not it is the target of the application. Shoes quickly become contaminated when walking through such plant growth. When leather shoes become wet with spray material they have a tendency to become cracked and dried out to the extent that pesticide easily penetrates through to the sock or foot. Both leather and canvas shoes absorb chemicals and may hold

them in contact with the wearer. Boots should be washed and dried thoroughly, inside and out, as frequently as needed to remove any pesticide contaminant.

Workers in pesticide formulating plants should wear waterproof boots. Coverall pant legs should be worn outside the boot tops to prevent sifting of dry concentrated pesticide into the footwear.

RESPIRATORY ROUTE

Protection of the respiratory route is especially important where toxic dusts and vapors or very small spray droplets are prevalent, or where application is in confined spaces. Extremely fine particles and droplets found in dusts and mists are much more easily drawn into the respiratory system than the larger droplets formed by most conventional dilute spray machines. Our tests have shown that when operating an 8X (eight times the normal dilute concentration) concentrate airblast machine in fruit orchards the potential respiratory exposure is nearly 3 times greater than when operating the conventional dilute machine.[6]

Respiratory protection for most types of application can be provided by use of cartridge-type respirators or, in certain cases, gas masks with special cannisters which have greater adsorbent capacity than the cartridges. Applicator pilots who risk the possibility of flying through drift of fine droplets or dusts should use a face mask equipped with a filter cannister and attached either to their belt or to the inside of the cockpit. When fumigating or applying highly toxic pesticides in confined spaces it is advisable to use a respirator with a special compressed air supply tank so that none of the contaminated ambient air is inhaled.

Proper care of respirators is very important to the protection of the workers. The rubber face-piece becomes hardened and the head straps lose their elasticity with age and exposure to heat and sunlight. These conditions lead to poor fit and allow leakage around the face-piece. Two of the more common offenses in the care of respirators that we have observed are (1) failing to occasionally wash the face-piece with soap and water and (2) neglecting to change the filter cartridges or cannisters regularly. Washing of the face-piece of a cartridge-type respirator should not be attempted while the cartridges are in place as moisture may contact the activated charcoal filter material and reduce its effectiveness in adsorption and absorption

of pesticides. Solvents should not be used as a cleaner for they may damage certain parts of the respirator. The general recommendation is that cartridges should be changed after 8 hours of continuous exposure. In most application situations this leaves much up to the individual worker to keep a record of his respirator exposure time. In a formulating plant where hours of exposure are more regular this is more easily controlled under the guidance of a foreman. Under conditions of intense exposure the useful life of the cartridge is much shorter. Thus, if the breathing seems hampered, or if the odor of pesticide is detected, the filter cartridges should be changed immediately. If the outer filter pads are separate removable units they should be changed more frequently than the cartridges.

During discussions of the respiratory route of entry into the body the question is often raised concerning the hazard of smoking pesticide-contaminated cigarettes. We have found it difficult to measure such potential exposure with any great degree of accuracy. The technique we have utilized thus far involves subjecting the cigarettes to normal handling through the process of removing them from the pack and placing them in the mouth, lighting them, and smoking one-half the cigarette. The remainder of the cigarette is then analyzed for pesticide content. The values obtained are based on the assumption that pesticide on the cigarette will be volatilized before being broken down by burning and that none of the volatile or particulate pesticide would be trapped in the butt end of the cigarette. In observing smoking by workers it was noted that the area of greatest contamination of the cigarette was far enough from the butt end to allow burning of the contaminated area in most cases.

In studies of cigarette contamination by spraymen applying endrin in orchards, the potential exposure through smoking during application operations was calculated to be not more than 0.002 mg per cigarette, even when the cigarettes were handled with hands wet with the dilute spray.[8] In later studies[7] involving spraymen applying parathion to apple orchards by airblast machines, from 0.003 to 0.005 mg of parathion per cigarette could be recovered where they were handled with hands that were contaminated but dry. When handled with hands that were wet enough with dilute spray to leave moist spots on the cigarette paper from 0.020 to 0.050 mg could be found. In a controlled study designed to determine what might be the maximum contamination of cigarettes through such handling, hands were dipped in 45% emulsifiable concentrate parathion, the hands

wiped off lightly on the trousers, and the cigarettes were handled to simulate smoking. The highest value found was 0.235 mg per cigarette.

Even though values for potential respiratory exposure through smoking contaminated cigarettes may not appear to reflect any great hazard, two important points must be kept in mind: (1) Pesticide entering by the respiratory route is practically 100% absorbed, and (2) There is no assurance that a more toxic breakdown product will not be formed and inhaled as the high temperature of a burning cigarette reaches the contaminated areas rather than complete destruction of the compound by burning. For example, in the case of parathion the oxidation product, paraoxon, is estimated to be much more toxic than the parent compound, possibly 100 to 500 times more toxic. This could be an important factor as far as hazard is concerned and emphasizes the need for recommending washing of hands and face before smoking.

ORAL ROUTE

There has been little experimental work conducted to define the magnitude of oral exposure. We are studying techniques at the present time. Analysis of saliva samples of exposed individuals appears to give some indication of contamination.

The most serious oral exposure may be brought about by splashing of liquid concentrate into the mouth while pouring and measuring pesticides. Contamination may also occur through licking the lips, by rubbing the mouth with contaminated arms or hands, by careless actions such as attempting to blow out clogged spray nozzles with the mouth, or by eating or drinking with contaminated hands.

We have attempted to measure the parathion contamination of typical sack lunch items, such as sandwiches, cookies, and pickles by workers whose hands had been contaminated while thinning fruit in recently sprayed apple orchards.[5] A lunch consisting of four half-sandwiches, two cookies, and one pickle was given to workers who handled and ate one-half of each item with unwashed hands. The other half of each item was analyzed for parathion. This provided potential oral exposure values for lunch items. A total of approximately 0.103 mg of parathion was found on the typical lunch mentioned above. Although this is not a great amount of pesticide, it would add to the total exposure of each individual; thus, workers should wash hands and face before eating.

ENTRY THROUGH CUTS OR ABRASIONS

Any break in the skin may allow a more direct route of entry into the blood stream. Even if the outer layer of dead cells (strateum corneum) of the skin is removed by scratching or scuffing the result may be a potential for increased absorption at that site as this layer of cells is considered the main barrier against chemicals. Maibach and Feldman[1] found that when most of these cells were removed by abrading through repeated application and removal of sticky tape, the absorption of parathion applied to the forearm could be increased more than 8-fold.

This route of entry is one that may not have received enough attention in the past. Cuts and abrasions occur most frequently on the hands, and unfortunately the hands are the body area most often in contact with the more concentrate forms of pesticides. There have been poisoning cases suspected as having been a result of entry by this route; however, there has not been enough evidence to definitely prove that this route played the major part in the illnesses.

One suspected poisoning case which might be used as an example involved a 25-year-old worker in a pesticide plant whose finger was crushed by a fork lift which appeared to be contaminated with concentrate parathion.[2] For several weeks prior to the accident he had been working primarily with carbaryl, along with a small amount of malathion, but nothing as toxic as parathion. The worker became severely ill and exhibited symptoms of poisoning within approximately 30 minutes of the accident, a coincidence which aroused suspicion that the illness was associated with the accident. Analysis of a blood sample showed cholinesterase activity to be very low. There was prompt clinical response to administration of atropine and 2-PAM. Although there does not appear to be enough evidence to prove entry of pesticide at the area of broken skin, the circumstances around the case indicate that this route of entry could possibly have played a major part in poisoning. In such case poisoning symptoms may not have developed had the worker been wearing gloves.

Another suspected case involved broken skin on the feet of a 54-year-old male who wore canvas shoes while spraying an apple orchard.[3] His shoes became soaked with the dilute spray from walking through wet cover crop. He had complained of "scalded feet" indicating raw, red, oozing areas especially on his soles and between his toes. On several occasions he was aided in bandaging his feet or procuring tape, etc. by co-workers. He had sprayed for several days but on the day of his death he had sprayed for 9 hours, wearing canvas shoes all day. A post-mortem blood sample showed very low cholinesterase. The physician investigating the case indicated that cause of death was parathion poisoning due to probable dermal absorption

particularly through an area of dermatitis on both feet. Because body areas other than the feet were exposed there is no complete assurance that this was the main route of entry of the compound. Nevertheless, this case points out the importance of wearing rubber boots or shoes while applying liquid pesticides.

DISCUSSION

Regardless of how specifically the measures for protection of workers from exposure to toxic pesticides may be stated for any particular situation, people who work with such compounds must realize that there is some element of risk involved. Accidents occur, even among workers who are careful. In case of accidental gross contamination of skin with a highly toxic compound every effort must be made to cleanse the contaminated area as quickly and as thoroughly as possible. The best recommendation at present is the use of plenty of soap and water. Wash by rubbing with the hands or with a piece of cloth. Do not scrub with a brush because the outer protective layer of the skin may be abraded enough to allow more rapid absorption of any pesticide not removed. A bar of soap, towel, and container of water should be carried on every pesticide application machine or accompanying vehicle for use in washing should a spillage occur. In the pesticide formulating plant shower facilities for use in case of accidental contamination are practically always near at hand. If pesticide gets in the eyes they should be thoroughly flushed with water for at least five minutes. If a person should feel ill while working with pesticides he should stop work at once and get medical attention. If his illness is diagnosed as being caused by a pesticide he should not return to work until a physician advises that it is safe to do so.

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PROTECTION OF WORKERS FROM EXPOSURE TO PESTICIDES

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EDITOR'S NOTE: Mr. Wolfe's comments should concern all workers who apply pesticides. This article is not specific for a particularly area, such as application of pesticides in or around structures. Rather, Mr. Wolfe embraces the need for continued vigilance against pesticide hazard wherever it is present. Many of the comments on protective clothing, for example, are not as applicable to structural pest control operators as they are to workers engaged in weed control or tree and ornamental spray operations. As they apply, Mr. Wolfe's observations — based on research — should be given high priority consideration.

PEST CONTROL WORKERS are often subjected to relatively high levels of toxic pesticides when actively engaged in pest control operations.

Illnesses resulting from overexposure to such compounds do occur among such workers. Most, however, are a result of carelessness or accident. Experience has shown that if proper precautionary measures are observed and directions on the pesticide label are followed, even the more toxic compounds can be used safely.

Even though there is an effort to insure that pesticides produced in the future will be low in toxicity to warm-blooded animals as well as not persistent in the environment, any great change in this direction will probably not take place in a very short period of time. Thus, at least in the immediate future, we may see continued, if not increased, use of compounds that are relatively toxic. In cases where a more acutely toxic compound is being used as a replacement for a less acutely toxic but more persistent so-called "hard pesticide," workers handling the material should be informed of the greater potential hazard involved. In consideration of the continued or increased use of such compounds, we should not become lax in our concern about protection of the worker. Protection of such persons from excess exposure is necessary if a good record for safe use and handling of pesticides is to be maintained.

Most of the modern synthetic insecticides used in pest control operations are organophosphorus, chlorinated hydrocarbon, or carbamate-type compounds. Generally, the acute toxity of the organophosphorus group is somewhat greater than that of the chlorinated hydrocarbons or carbamates. However, the chlorinated hydrocarbon compounds, due to their greater stability, present more of a residue problem.

Much of the safety in relation to pesticides rests on the user or applicator of the compounds. If he is knowledgeable concerning pesticides and understands the importance of taking proper precautions, he can do much to insure the safety of himself and others. Thus, an important adjunct to safety in relation to pesticides is education, not only of supervisory personnel but also of those individuals who actually handle or apply the materials.

There are several very important indirect ways of protecting the pest control worker such as providing education and medical supervision, stressing the importance of personal hygiene and cleanliness, emphasizing the importance of not being careless, and pointing out the need for reading and following directions on the pesticide label. However, these topics will covered elsewhere and this presentation will be limited to discussion of the more direct protection of the various routes of entry of pesticides into the body. Protection of these routes means prevention of exposure and prevention of exposure is undoubtedly the best insurance against poisoning.

ROUTES OF ENTRY

There are four routes of entry of pesticide compounds into the body: (1) dermal, (2) respiratory, (3) oral, and (4) through cuts or abrasions in the skin.

Dermal Route:

The dermal route is considered to be the most

important route of entry into the body during most situations where exposure is to liquid pesticide formulations and probably plays an important part in exposure of workers in most any pest control operation regardless of the formulation being used. This route is one that has undoubtedly been responsible for a great many poisonings of workers, especially from the more toxic organophosphorus compounds.

In research studies we have measured the potential exposure of several hundred pesticide applicators, and the results indicate that over 97% of the pesticide to which the body is subjected during most exposure situations, and especially to applicators of liquid sprays, is deposited on the skin. It should be understood that any given amount of pesticide is more rapidly and more completely absorbed by the oral or respiratory routes. However, absorption of pesticides by these two routes is probably too small a fraction of the total potential exposure to be considered the main factor in most poisioning cases of workers in the field.

The importance of protecting specific body areas has not been clearly defined in the past. This is because the rate of absorption of different compounds through human skin is difficult to measure with any degree of accuracy. The most useful and probably most accurate estimations or measurements on the percutaneous penetration of pesticides in man which have been accomplished thus far have been made by Maibach **et al.**[1] Using radioactive labeled pesticides they were able to determine approximately what fraction of an applied dose would be absorbed through the skin. In this way they not only compared the degree of dermal absorption for certain pesticides but also compared absorption of a single pesticide for different parts of the human body. The results obtained indicate that in the past sufficient importance may not have been attached to protection of certain body areas.

In checking dermal penetration of parathion at different body areas these researchers found that the area of greatest absorption on man is the scrotum where approximately 100% of an applied dose was absorbed. The possibility of pesticide on this body area being completely absorbed is a very important point and emphasizes the need for increased concern about protection of the area. Of utmost importance would be the need for extreme caution in order to avoid spillage of highly toxic liquid pesticide onto the scrotum.

Although cloth coveralls or trousers provide a reasonable amount of protection where contamination does not easily penetrate clothing, the wearing of waterproof trousers provides the best protection for the lower trunk and leg areas and is especially recommended in work situations where there is a chance of liquid spillage, soaking by continued contact with more dilute liquid sprays, or penetration of clothing through excessive contact with dry pesticides. Needless to say, use of clean clothing and daily bathing in an effort to avoid excess dermal absorption are essential in any type of exposure situation.

Protection of the upper trunk and arms from contamination by toxic pesticides is important, especially under conditions where heavy spray drift may thoroughly wet cloth shirts, coveralls, and underclothing. Our studies have shown that the greatest potential contamination of spraymen in this general body are is the upper back, shoulders, and forearms of workers operating equipment which propels spray up into the air where it is more subject to drift. Under these conditions a waterproof jacket or raincoat provides the best protection for this general body area. This gear is usually worn during cooler conditions, but as the temperature rises and the clothing becomes unbearably hot to wear, workers tend to discard them and work with much less protection — perhaps only a short-sleeved T-shirt-type undershirt on the upper trunk area. Under such conditions workers should be encouraged to at least wear a long-sleeved cloth jacket or heavy grade shirt that will not be easily penetrated by pesticide, and preferably one that can be properly washed.

The wearing of long-sleeved heavy grade "GI" cotton shirts or coveralls as outer clothing during hot weather, often with no underclothing, is popular with many applicators even though this is not a recommended practice. Fortunately, these items of outer clothing provide a reasonable amount of protection where spray drift is light with very fine droplets that do not wet through to the skin. Under such conditions the clothing should be changed and laundered daily. If clothing used during spraying such as shirts, jackets, or coveralls are merely hung up to dry after work and used repeatedly, as is often the practice, it doesn't take long for the pesticide material to work through where it will make contact with underclothes or skin.

In selecting protective clothing for workers it is important to take into consideration the comfort of the individual when he wears such items. The conventional black or dark green rubberized or plastic waterproof jackets in common use during past years are considered by many applicators to be uncomfortable to wear not only because of greater heat absorption but also because they may be of heavy grade material and not very flexible. During recent years, however, several jackets and jacket-trouser combinations that are lighter in color and weight have been available. Although less durable, they are less costly to replace. Nevertheless, there is still considerable discomfort in

wearing any waterproof clothing during hot weather because of the trapping of body heat. Disposable paper jackets have been tested and found suitable for use only under conditions where heavy wetting does not occur. Such paper jackets were found to be much cooler and thus more comfortable than other jackets tested.

Observations of pesticide applicators have indicated that although waterproof clothing items, and especially jackets, are usually carried by the workers, or readily available to them, they usually will not don the clothing until drift of pesticide increases to the point where they feel protection is necessary. Unfortunately, by this time there is often considerable contamination of skin and clothing. The covering of contaminated skin areas by waterproof clothing may create conditions under which dermal absorption may be increased. This may be more important during hot weather where high temperatures and perspiration are involved. Whether or not there would be less absorption under these conditions than if the clothing were left off entirely depends upon the potential exposure which might occur after the worker puts on the clothing. Although the amount of increase in absorption of pesticides by covering contaminated skin with various items of protective clothing is not known, it is certainly sound advice to put on protective gear **before** the skin has been contaminated to any great degree.

Results of the dermal absorption studies noted above indicate that the head-neck area should be given more attention. In this area absorption of parathion was found to be from 32.2 to 36.3% of an applied dose;[1] much more than we would have anticipated and more than at other areas of the body studied with the exception of the armpit and scrotum. When observing pesticide applicators it is easy to conclude that the face-neck area is usually less protected than most other parts of the body. Head coverings or caps used are often made of material that allows easy penetration of pesticide onto the scalp. The headgear may have no bill or brim which would provide some added protection to the face-neck area, especially from pesticide material which drifts downward.

Protection from downward drift is especially important during application of liquid sprays. The headgear most commonly used by pesticide applicators is the billed cap which provides some protection for the face but very little for the remainder of the head-neck area other than the scalp. The conventional "Sou'wester" rain hat, often used when heavy downward drift occurs, does not provide exceptionally good protection for the face and sides of the neck. This is because of the narrow brim in all areas except at the back of the neck. Metal or fiber "hard hats" are also used to some extent; however, most have too narrow a brim to provide adequate protection. "Hard hats" which allow circulation of air over the head under the hat should not be used where exposure is to toxic dusts.

Our studies have shown that the greatest protection from downward drift of pesticides is afforded by some type of wide-brimmed hat, preferably made of water-repellent material. Waterproof hats, other than the "Sou'wester," were not readily available at that time. However, one is now available which is waterproof and also has a wide brim that affords good protection of the face-neck area. This type of hat should be recommended for use by all applicators who may be subjected to downward drift of pesticides.

Of particular interest in relation to exposure of the head-neck area is the finding by Maibach and co-workers[1] that absorption of parathion is relatively efficient (46.6% of applied dose) in the ear canal. Exposure in this area could occur through drift of fine pesticide mists or dusts or by digging in the ear with the tip of a contaminated finger.

It is of importance to note that wearing goggles and respirators provides considerable protection to the face as well as to the eyes.

Although a statement suggesting the use of goggles can be found on certain pesticide labels, they are not often worn except by pilots who apply pesticides by aircraft. Questioning of pilots has revealed that they wear goggles not only to prevent poisoning and to keep wind out of the eyes but also to prevent certain organophosphorus pesticides that are direct inhibitors of cholinesterase from causing miosis. This is understandable because it has been shown that unilateral contamination of the eye with TEPP may cause pilots to inadequately judge distance.[2] The incoordination which may accompany this could be a serious threat to safety.

The hands are often the body area having the highest exposure to pesticides and they have greater chance of coming in contact with the more concentrate formulations. They are also more subject to cuts or abrasions, which will be discussed later.

High potential exposure to the hands brings attention to the need for wearing gloves. Some people who have worked with pesticides feel it is better not to wear gloves than to wear gloves that are contaminated on the inside; something which invariably occurs to some degree. Our research concerning the use of protective gloves indicates that, unless there is gross contamination of the inside of the gloves, the potential exposure is less when wearing gloves than when not wearing them. If gloves are kept clean on the inside there is very little doubt concerning the value of their use when handling pesticides. Unlined rub-

ber gauntlet gloves provide the best protection because the gauntlet covers the wrist area not normally covered by the jacket sleeve and they can be turned wrong side out for proper cleansing of the unlined inside surface.

Heavyweight gloves, although durable, do not allow adequate freedom of movement, especially finger flexibility, and they are also difficult to turn inside-out for cleaning. On the other hand, some lightweight gloves, although flexible enough to allow freedom of finger movement, wear out rapidly and are easily torn. Therefore, it is advisable to secure gloves of a grade that is somewhat durable but yet light enough to be flexible and thus more acceptable to the worker.

Waterproof shoes or boots should be worn when handling or applying pesticides on a large scale. During liquid spray operations the ground cover of weeds, grasses, or other plants invariably becomes wet with dilute pesticide regardless of whether or not it is the target of the application. Shoes quickly become contaminated when walking through such plant growth or when spraying downward with a fine mist that drifts toward the feet. When leather shoes become wet with spray material they have a tendency to become cracked and dried out to the extent that pesticide easily penetrates through to the sock or foot. Both leather and canvas shoes absorb chemicals and may hold them in contact with the wearer. Waterproof boots should be washed and dried thoroughly, inside and out, as frequently as needed to remove any pesticide contaminant.

Respiratory Route:

Protection of the respiratory route is especially important where toxic dusts and vapors or very small spray droplets are prevalent, or where application is in confined spaces. Extremely fine particles and droplets found in dusts and mists are much more easily drawn into the respiratory system than the larger droplets formed by most conventional dilute spray machines.

Respiratory protection for most types of application can be provided by use of cartridge-type respirators or, in certain cases, gas masks with special cannisters which have greater absorbent capacity than the cartridges. Applicator pilots who risk the possibility of flying through drift of fine droplets or dusts should use a face mask equipped with a filter cannister and attached either to their belt or to the inside of the cockpit. When fumigating or applying highly toxic pesticides in confined spaces it is advisable to use a respirator with a special compressed air supply tank so that none of the contaminated ambient air is inhaled.

Proper care of respirators is very important to the protection of the workers. The rubber face-piece becomes hardened and the head straps lose their elasticity with age and exposure to heat and sunlight. These conditions lead to poor fit and allow leakage around the face-piece. Two of the more common offenses in the care of respirators that we have observed are (1) failing to occasionally wash the face-piece with soap and water and (2) neglecting to change the filter cartridges or cannisters regularly. Washing of the face-piece of a cartridge-type respirator should not be attempted while the cartridges are in place as moisture may contact the activated charcoal filter material and reduce its effectiveness in absorption and absorption of pesticides. Solvents should not be used as a cleaner for they may damage certain parts of the respirator. The general recommendation is that cartridges should be changed after 8 hours of continuous exposure. In most application situations this leaves much up to the individual worker to keep a record of his respirator exposure time. Where hours of exposure are more regular this can be more easily controlled under the guidance of a foreman. Under conditions of intense exposure the useful life of the cartridge is much shorter. Thus, if breathing seems hampered, or if the odor of pesticide is detected, the filter cartridges should be changed immediately. If the outer filter pads are separate removable units they should be changed more frequently than the cartridges.

During discussions of the respiratory route of entry into the body the question is often raised concerning the hazard of smoking pesticide-contaminated cigarettes. We have found it difficult to measure such potential exposure with any great degree of accuracy. The technique we have utilized thus far involves subjecting the cigarettes to normal handling through the process of removing them from the pack and placing them in the mouth, lighting them, and smoking one-half the cigarette. The remainder of the cigarette is then analyzed for pesticide content. The values obtained are based on the assumption that pesticide on the cigarette will be volatilized before being broken down by burning and that none of the volatile or particulate pesticide would be trapped in the butt end of the cigarette. Of course, this may not be what occurs under actual smoking conditions but it provides some type of a guideline as to the potential exposure from a cigarette. In observing smoking by workers it was noted that in most cases the area of greatest contamination of the cigarette was far enough from the butt end to allow burning of the contaminated area before the cigarette butt was discarded.

In studies of cigarette contamination by spraymen applying endrin in orchards, the potential

exposure through smoking during application operations was calculated to be not more than 0.002 mg per cigarette, even when the cigarettes were handled with hands wet with the dilute spray.[3] In later studies[4] involving spraymen applying parathion to apple orchards by airblast machines, from 0.003 to 0.005 mg of parathion per cigarette could be recovered when they were handled with hands that were contaminated but dry. When handled with hands that were wet enough with dilute spray to leave moist spots on the cigarette paper from 0.020 to 0.050 mg could be found. In a controlled study designed to determine what might be the maximum contamination of cigarettes through such handling, hands were dipped in 45% emulsifiable concentrate parathion, the hands wiped off lightly on the trousers, and the cigarettes were handled to simulate smoking. The highest value found was 0.235 mg per cigarette.

Even though values for potential respiratory exposure through smoking contaminated cigarettes may not appear to reflect any great hazard, two important points must be kept in mind: (1) A pesticide entering by the respiratory route is practically 100% absorbed, and (2) There is no assurance that a more toxic breakdown product will not be formed and inhaled as the high temperature of a burning cigarette reaches the contaminated areas rather than complete destruction of the compound by burning. For example, in the case of parathion the oxidation product, paraoxon, is estimated to be much more toxic than the parent compound, possibly 100 to 500 times more toxic. This could be an important factor as far as hazard is concerned and emphasizes the need for recommending washing of hands and face before smoking.

Oral Route:

There has been little experimental work conducted to define the magnitude of oral exposure. We are studying techniques at the present time. Analysis of saliva samples of exposed individuals appears to give some indication of contamination.

The most serious oral exposure may be brought about by splashing of liquid concentrate into the mouth while pouring and measuring pesticides. Contamination may also occur through licking the lips, by rubbing the mouth with contaminated arms or hands, by careless actions such as attempting to blow out clogged spray nozzles with the mouth, or by eating or drinking with contaminated hands. Workers should wash hands and face before eating, drinking, or smoking.

Entry Through Cuts or Abrasions:

This route of entry is one that may not have received enough attention in the past. Cuts and abrasions occur most frequently on the hands, and, unfortunately, the hands are the body area most often in contact with the more concentrate forms of pesticides.

Any break in the skin may allow a more direct route of entry into the blood stream. Even if the outer layer of dead cells (strateum corneum) of the skin is removed by scratching or scuffing the result may be a potential for increased absorption at that site as this layer of cells is considered the main barrier against chemicals. There have been poisoning cases suspected as having been a result of entry through cuts or abrasions. However, there has not been enough evidence to definitely prove that this route played the major part in the illnesses.

DISCUSSION

Regardless of how specifically the measures for protection of workers from exposure to toxic pesticides may be stated for any particular situation, people who work with such compounds must realize that there is some element of risk involved. Accidents occur, even among workers who are careful. In case of accidental gross contamination of skin with a highly toxic compound every effort must be made to cleanse the contaminated area as quickly and as thoroughly as possible. The recommendation at present is the use of plenty of soap and water. Wash by rubbing with the hands or with a piece of cloth. Do not scrub with a brush because the outer protective layer of the skin may be abraded enough to allow more rapid absorption of any pesticide not removed. A bar of soap, towel, and container of water should be carried on every pesticide application machine or accompanying vehicle for use in washing should a spillage occur. If pesticide gets in the eyes they should be thoroughly flushed with water for at least five minutes. If a person should feel ill while working with pesticides he should stop work at once and get medical attention. If his illness is diagnosed as being caused by a pesticide he should not return to work until a physician advises that it is safe to do so.

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Hazards to and Protection of Individuals Who Mix or Apply Pesticides

By

Homer R. Wolfe *

Man is often subjected to relatively high levels of pesticide compounds when he is actively engaged in pest control operations or working directly with the compounds in formulating plants. Experience has shown that if proper precautionary measures and directions are followed, even the more toxic compounds can be handled safely. Although illnesses and even deaths from pesticides occur each year in the United States, it should be pointed out that most of these cases are caused by carelessness or by accident.

The more extensively used modern synthetic insecticides are the organophosphorus, chlorinated hydrocarbon, and carbamate compounds. Generally, the acute toxicity of the organophosphorus group is somewhat greater than that of the chlorinated hydrocarbon or the carbamate compounds. However, the chlorinated hydrocarbon compounds, due to their greater stability, present more of a residue problem. The estimation of hazard to workers who come in contact with pesticides is based primarily on the observed acute dermal, and to a less extent oral, toxicity of these compounds to experimental animals. Where it is available, use experience is considered. The estimated relative acute toxic hazard to spraymen for a number of pesticides can be seen in the table. The classification into toxicity groups is both approximate and relative. It should be noted that these toxicity categories are not related to specific categories spelled out for label requirements.

Much of the safety in relation to pesticides rests on the user or applicator of the compounds. If he is knowledgeable concerning pesticides and understands the importance of taking proper precautions, he can do much to insure the safety of himself and others. This also applies to workers involved in the manufacture and formulation of toxic compounds. Their contact is usually with the more concentrated forms of pesticides; therefore, they should be especially aware of the need for protecting themselves from exposure. Thus, an important adjunct to safety in relation to pesticides is education, not only of supervisory personnel but also of those individuals who actually handle the materials.

There are several very important indirect ways of protecting the worker such as providing education and medical supervision, stressing the

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importance of personal hygiene and cleanliness, the importance of not being careless, and pointing out the need for reading and following directions on the pesticide label. However, these topics will be covered by other presentations on this program. The main purpose of this presentation is to discuss the more direct protection of the various routes of entry of pesticide into the body. Protection of these routes means prevention of exposure and prevention of exposure is undoubtedly the best insurance against poisoning.

ROUTES OF ENTRY

There are four routes of entry of pesticide compounds into the body: (1) dermal, (2) respiratory, (3) oral, and (4) through cuts or abrasions in the skin.

DERMAL ROUTE

The dermal route is considered to be the most important route of entry into the body during most exposure situations in the field and probably plays an important part in exposure of workers in formulating plants. This route is one that has undoubtedly been responsible for a great many poisonings of workers, especially from the more toxic organophosphorus compounds.

In research studies we have measured the potential exposure of several hundred pesticide applicators, and the results indicate that over 97% of the pesticide to which the body is subjected during most exposure situations, and especially to applicators of liquid sprays, is deposited on the skin. It should be understood that any given amount of pesticide is more rapidly and more completely absorbed by the oral or respiratory routes. However, absorption of pesticides by these two routes is probably too small a fraction of the total potential exposure to be considered the main factor in most poisoning cases of workers in the field.

The importance of protecting specific body areas has not been clearly defined in the past. This is because the rate of absorption of different compounds through human skin is difficult to measure with any degree of accuracy. The most useful and probably most accurate estimations or measurements on the percutaneous penetration of pesticides in man which have been accomplished thus far have been made by Maibach and Feldman.[1] Using radioactive labeled pesticides they were able to determine approximately what fraction of an applied dose would be absorbed through the skin. In this way they not only compared the degree of dermal absorption for certain pesticides but also compared absorption of a single pesticide for different parts of the human body. The results obtained indicate that sufficient importance may not have been attached to protection of certain body areas. In checking dermal penetration of parathion at different body areas these researchers found that the area of greatest absorption on man is the scrotum where approximately 100% of an applied dose was absorbed. The possibility of pesticide on this body area being

completely absorbed is a very important point and emphasizes the need for increased concern about protection of the area. Of utmost importance would be the need for extreme caution in order to avoid spillage of highly toxic liquid pesticide onto the scrotum.

Although cloth coveralls or trousers provide a reasonable amount of protection where contamination does not easily penetrate clothing, the wearing of waterproof trousers provides the best protection for the lower trunk and leg areas and is especially recommended in work situations where there is a chance of liquid spillage, soaking by continued contact with more dilute liquid sprays, or penetration of clothing through excessive contact with dry pesticides. In formulating plants where the main outer protective garment is usually cotton coveralls, workers should be required to wear waterproof aprons, especially if they are on duty at bagging or mixing stations where there is often considerable contamination down the front of the clothing with relatively concentrated wettable powder formulations. Fortunately, many plants require the use of aprons. Even when the waterproof apron is used it is very important that the worker change to freshly laundered clothing each day in order to prevent contamination of the scrotum or other skin areas. Needless to say, use of clean clothing and daily bathing in an effort to avoid excess dermal absorption are essential in any type of exposure situation.

Protection of the upper trunk and arms from contamination by toxic pesticides is important, especially under conditions where heavy spray drift may thoroughly wet cloth shirts, coveralls, and underclothing or where concentrated dry pesticides come in contact with clothing and skin in formulating plants. Our studies have shown that the greatest potential contamination of spraymen in this general body area is the upper back, shoulders, and forearms of workers operating equipment which propels spray up into the air where it is more subject to drift. Under these conditions a waterproof jacket or raincoat provides the best protection for this general body area. This gear is usually worn during cooler conditions, but as the temperature rises and the clothing becomes unbearably hot to wear, workers tend to discard them and work with much less protection--perhaps only a short-sleeved T-shirt-type undershirt on the upper trunk area. Under such conditions workers should be encouraged to at least wear a long-sleeved cloth jacket that will not be easily penetrated by pesticide, and preferably one that can be properly washed.

The wearing of long-sleeved heavy grade "GI" cotton shirts or coveralls as outer clothing during hot weather, often with no underclothing, is popular with many applicators even though this is not a recommended practice. Fortunately, these items of outer clothing provide a reasonable amount of protection where spray drift is light with very fine droplets that do not wet through to the skin. Under such conditions the clothing should be changed and laundered daily. If clothing used during spraying such as shirts, jackets, or coveralls are merely hung up to dry after work and used repeatedly, as is often the practice, it doesn't take

long for the pesticide material to work through where it will make contact with underclothes or skin.

In selecting protective clothing for workers it is important to take into consideration the comfort of the individual when he wears such items. The conventional black or dark green rubberized or plastic waterproof jackets in common use during past years are considered by many applicators to be uncomfortable to wear not only because of greater heat absorption but also because they may be of heavy grade material and not very flexible. During recent years, however, several jackets and jacket-trouser combinations that are lighter in color and weight have been available. Although less durable, they are less costly to replace. Nevertheless, there is still considerable discomfort in wearing any waterproof clothing during hot weather because of the trapping of body heat.

Observations of pesticide applicators have indicated that although waterproof clothing items, and especially jackets, are usually carried by the workers, or readily available to them, they usually will not don the clothing until drift of pesticide increases to the point where they feel protection is necessary. Unfortunately, by this time there is often considerable contamination of skin and clothing. The covering of contaminated skin areas by waterproof clothing may create conditions under which dermal absorption may be increased. This may be more important during hot weather where high temperatures and perspiration are involved. Whether or not there would be less absorption under these conditions than if the clothing were left off entirely depends upon the potential exposure which might occur after the worker puts on the clothing. Maibach and Feldman[1] found that covering up (occlusion) of contaminated skin with thin plastic wrap material caused approximately a four-fold increase in absorption of parathion. Although the increase of absorption of pesticide by covering contaminated skin with various items of protective clothing is not known, the above occlusion test results are cause to emphasize the need to put on protective gear <u>before</u> the skin has been contaminated to any great degree.

The use of waterproof jackets in pesticide formulating plants is not common and generally not considered a requirement if, as stated earlier, rubber aprons are worn and coveralls are kept clean. It should be noted, however, that in a plant there is more ready access to showers and other means of decontamination, should excess exposure occur, than in the field where applicators work.

Results of the dermal absorption studies noted above indicate that the head-neck area should be given more attention. In this area absorption of parathion was found to be from 32 to 47% of an applied dose;[1] much more than we would have anticipated and more than at other areas of the body studied with the exception of the armpit and scrotum. When observing either pesticide applicators or workers in formulating plants it is easy to conclude that the face-neck area is less protected than most other parts of the body. Head coverings or caps used in formulating plants are often made of material that allows easy penetration of pesticide onto the scalp. The headgear may have no bill or brim which would provide some

added protection to the face-neck area, especially from pesticide material which drifts downward.

Protection from downward drift is especially important during application of liquid sprays. The headgear most commonly used by pesticide applicators is the billed cap which provides some protection for the face but very little for the remainder of the head-neck area other than the scalp. The conventional "Sou'wester" rain hat, often used when heavy downward drift occurs, does not provide exceptionally good protection for the face and sides of the neck. This is because of the narrow brim in all areas except at the back of the neck. Metal or fiber "hard hats" are also used to some extent; however, most have too narrow a brim to provide adequate protection. "Hard hats" which allow circulation of air over the head under the hat should not be used where exposure is to toxic dusts.

Our studies have shown that the greatest protection from downward drift of pesticides is afforded by some type of wide-brimmed hat, preferably made of water-repellent material. Waterproof hats, other than the "Sou'wester," were not readily available at that time. However, one is now available which is waterproof and also has a wide brim that affords good protection of the face-neck area. This type of hat should be recommended for use by all applicators who may be subjected to downward drift of pesticides.

Of particular interest in relation to exposure of the head-neck area is the finding by Maibach and Feldman[1] that absorption of parathion is relatively efficient (47% of applied dose) in the ear canal. Exposure in this area could occur through drift of fine pesticide mists or dusts or by digging in the ear with the tip of a contaminated finger. Of particular importance is the potential for drift into the ear of concentrated dry formulations of toxic compounds in the formulating plant.

It is of importance to note that wearing goggles and respirators provides considerable protection to the face.

Although a statement suggesting the use of goggles can be found on certain pesticide labels, they are rarely worn except by pilots who apply pesticides by aircraft. Questioning of pilots has revealed that they wear goggles not only to prevent poisoning and to keep wind out of the eyes but also to prevent certain organophosphorus pesticides that are direct inhibitors of cholinesterase from causing miosis. This is understandable because it has been shown that unilateral contamination of the eye with TEPP may cause pilots to inadequately judge distance.[2] The incoordination which may accompany this could be a serious threat to safety.

The hands are often the body area having the highest exposure to pesticides and they have a greater chance of coming in contact with the more concentrate formulations. They are also more subject to cuts or abrasions, which will be discussed later.

High potential exposure to the hands brings attention to the need for wearing gloves. Some people who have worked with pesticides feel it is better not to wear gloves than to wear gloves that are contaminated on the inside; something which invariably occurs to some degree. Our research concerning the use of protective gloves indicates that, unless there is gross contamination of the inside of the gloves, the potential exposure is less when wearing gloves than when not wearing them. If gloves are kept clean on the inside there is very little doubt concerning the value of their use when handling pesticides. Unlined rubber gauntlet gloves provide the best protection because the gauntlet covers the wrist area not normally covered by the jacket sleeve and they can be turned wrong side out for proper cleansing of the unlined inside surface.

Waterproof shoes or boots should be worn when handling or applying pesticides on a large scale. During liquid spray operations the ground cover of weeds, grasses, or other plants invariably becomes wet with dilute pesticide regardless of whether or not it is the target of the application. Shoes quickly become contaminated when walking through such plant growth. When leather shoes become wet with spray material they have a tendency to become cracked and dried out to the extent that pesticide easily penetrates through to the sock or foot. Both leather and canvas shoes absorb chemicals and may hold them in contact with the wearer. Boots should be washed and dried thoroughly, inside and out, as frequently as needed to remove any pesticide contaminant.

Workers in pesticide formulating plants should wear waterproof boots. Coverall pant legs should be worn outside the boot tops to prevent sifting of dry concentrated pesticide into the footwear.

RESPIRATORY ROUTE

Protection of the respiratory route is especially important where toxic dusts and vapors or very small spray droplets are prevalent, or where application is in confined spaces. Extremely fine particles and droplets found in dusts and mists are much more easily drawn into the respiratory system than the larger droplets formed by most conventional dilute spray machines. Our tests have shown that when operating an 8X (eight times the normal dilute concentration) concentrate airblast machine in fruit orchards the potential respiratory exposure is nearly 3 times greater than when operating the conventional dilute machine.[3]

Respiratory protection for most types of application can be provided by use of cartridge-type respirators or, in certain cases, gas masks with special cannisters which have greater adsorbent capacity than the cartridges. Applicator pilots who risk the possibility of flying through drift of fine droplets or dusts should use a face mask equipped with a filter cannister and attached either to their belt or to the inside of the cockpit. When fumigating or applying highly toxic pesticides in confined spaces it is advisable to use a respirator with a special compressed air supply tank so that none of the contaminated ambient air is inhaled.

Proper care of respirators is very important to the protection of the workers. The rubber face-piece becomes hardened and the head straps lose their elasticity with age and exposure to heat and sunlight. These conditions lead to poor fit and allow leakage around the face-piece. Two of the more common offenses in the care of respirators that we have observed are (1) failing to occasionally wash the face-piece with soap and water and (2) neglecting to change the filter cartridges or cannisters regularly. Washing of the face-piece of a cartridge-type respirator should not be attempted while the cartridges are in place as moisture may contact the activated charcoal filter material and reduce its effectiveness in adsorption and absorption of pesticides. Solvents should not be used as a cleaner for they may damage certain parts of the respirator. The general recommendation is that cartridges should be changed after 8 hours of continuous exposure. In most application situations this leaves much up to the individual worker to keep a record of his respirator exposure time. In a formulating plant where hours of exposure are more regular this is more easily controlled under the guidance of a foreman. Under conditions of intense exposure the useful life of the cartridge is much shorter. Thus, if the breathing seems hampered, or if the odor of pesticide is detected, the filter cartridges should be changed immediately. If the outer filter pads are separate removable units they should be changed more frequently than the cartridges.

During discussions of the respiratory route of entry into the body the question is often raised concerning the hazard of smoking pesticide-contaminated cigarettes. We have found it difficult to measure such potential exposure with any great degree of accuracy. The technique we have utilized thus far involves subjecting the cigarettes to normal handling through the process of removing them from the pack and placing them in the mouth, lighting them, and smoking one-half the cigarette. The remainder of the cigarette is then analyzed for pesticide content. The values obtained are based on the assumption that pesticide on the cigarette will be volatilized before being broken down by burning and that none of the volatile or particulate pesticide would be trapped in the butt end of the cigarette. In observing smoking by workers it was noted that the area of greatest contamination of the cigarette was far enough from the butt end to allow burning of the contaminated area in most cases.

In studies of cigarette contamination by spraymen applying endrin in orchards, the potential exposure through smoking during application operations was calculated to be not more than 0.002 mg per cigarette, even when the cigarettes were handled with hands wet with the dilute spray.[4] In later studies[5] involving spraymen applying parathion to apple orchards by airblast machines, from 0.003 to 0.005 mg of parathion per cigarette could be recovered where they were handled with hands that were contaminated but dry. When handled with hands that were wet enough with dilute spray to leave moist spots on the cigarette paper from 0.020 to 0.050 mg could be found. In a controlled study designed to determine what might be the maximum contamination of cigarettes through such

handling, hands were dipped in 45% emulsifiable concentrate parathion, the hands wiped off lightly on the trousers, and the cigarettes were handled to simulate smoking. The highest value found was 0.235 mg per cigarette.

Even though values for potential respiratory exposure through smoking contaminated cigarettes may not appear to reflect any great hazard, two important points must be kept in mind: (1) Pesticide entering by the respiratory route is practically 100% absorbed, and (2) There is no assurance that a more toxic breakdown product will not be formed and inhaled as the high temperature of a burning cigarette reaches the contaminated areas rather than complete destruction of the compound by burning. For example, in the case of parathion the oxidation product, paraoxon, is estimated to be much more toxic than the parent compound, possibly 100 to 500 times more toxic. This could be an important factor as far as hazard is concerned and emphasizes the need for recommending washing of hands and face before smoking.

ORAL ROUTE

There has been little experimental work conducted to define the magnitude of oral exposure. We are studying techniques at the present time. Analysis of saliva samples of exposed individuals appears to give some indication of contamination.

The most serious oral exposure may be brought about by splashing of liquid concentrate into the mouth while pouring and measuring pesticides. Contamination may also occur through licking the lips, by rubbing the mouth with contaminated arms or hands, by careless actions such as attempting to blow out clogged spray nozzles with the mouth, or by eating or drinking with contaminated hands. Workers should wash hands and face before eating, drinking, or smoking.

ENTRY TRHOUGH CUTS OR ABRASIONS

This route of entry is one that may not have received enough attention in the past. Cuts and abrasions occur most frequently on the hands, and unfortunately the hands are the body area most often in contact with the more concentrate forms of pesticides.

Any break in the skin may allow a more direct route of entry into the blood stream. Even if the outer layer of dead cells (strateum corneum) of the skin is removed by scratching or scuffing the result may be a potential for increased absorption at that site as this layer of cells is considered the main barrier against chemicals. Maibach and Feldman[1] found that when most of these cells were removed by abrading through repeated application and removal of sticky tape, the absorption of parathion applied to the forearm could be increased more than 8-fold. There have been poisoning cases suspected as having been a result of entry through cuts or abrasions. However, there has not been enough evidence to definitely prove that this route played the major part in the illnesses.

DISCUSSION

Regardless of how specifically the measures for protection of workers from exposure to toxic pesticides may be stated for any particular situation, people who work with such compounds must realize that there is some element of risk involved. Accidents occur, even among workers who are careful. In case of accidental gross contamination of skin with a highly toxic compound every effort must be made to cleanse the contaminated area as quickly and as thoroughly as possible. The best recommendation at present is the use of plenty of soap and water. If pesticide gets in the eyes they should be thoroughly flushed with water for at least five minutes. If a person should feel ill while working with pesticides he should stop work at once and get medical attention. If his illness is diagnosed as being caused by a pesticide he should not return to work until a physician advises that it is safe to do so.

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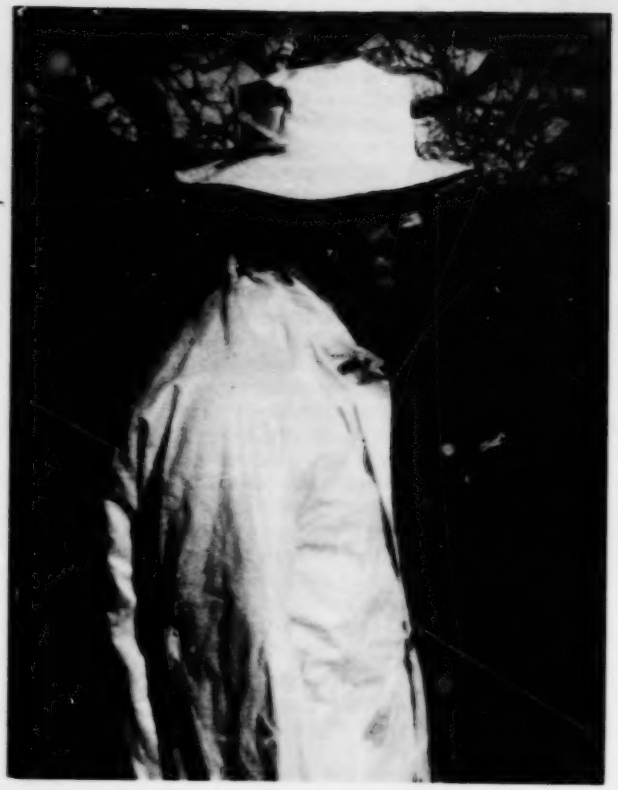
ESTIMATED RELATIVE ACUTE TOXIC HAZARDS OF PESTICIDES TO SPRAYMEN

The estimates of hazards in this table are based primarily on the observed acute dermal and to a less extent oral toxicity of these compounds to experimental animals. Where it is available, use experience has also been considered. It should be noted that the classification into toxicity groups is both approximate and relative. These toxicity categories are not related to specific categories spelled out for label requirements.

MOST DANGEROUS	DANGEROUS	LESS DANGEROUS*	LEAST DANGEROUS
Bidrin	Aldrin	Akton	Abate
Carbanolate (Temik)	Azodrin	Azinophos-Methyl (Guthion)	Alar
Carbofuran (Furadan)	Baygon	Binapacryl (Morocide)	Aramite
Dasanit	Bidrin	BHC	Bromophos
Demeton (Systox)	Bux	Chlordane	Captan
Disulfoton (Di-Syston)	Carbophenothion (Trithion)	Ciodrin	Carbaryl (Sevin)
Dyfonate	Dichlorvos (DDVP)	Coumaphos (Co-Ral)	Chlorobenzilate
Lannate	Dieldrin	Diazinon	2,4-D
Mevinphos (Phosdrin)	Dioxathion (Delnav)	Dicapthon	DDT
Monitor	DNOC	Dichloroethyl ether	Dicofol (Kelthane)
Parathion	DNOSBP	~~Dichlorvos (DDVP)~~	Dilan
Phorate (Thimet)	Endrin	Dimethoate	Dinocap (Karathane)
Schradan (OMPA)	EPN	Dinobuton (Dessin)	Diquat
TEPP	Methyl parathion	Endosulfan (Thiodan)	Gardona
Zinophos (Cynem)	Nicotine	Ethion	Malathion
	Paraquat	Fenthion (Baytex)	Maneb
	Pentachlorophenol	Fundal	Methoxychlor
	Phosphamidon	Galecron	Mirex
	Zectram	Heptachlor	Morestan
	Zolone	Imidan	NAA
		Lead Arsenate	Omite
		Lindane	Perthane
		Naled (Dibrom)	Phostex
		Oxydemetonmethyl (Meta-Systox-R)	Piperonyl butoxide
		Ruelene	Ronnel (Korlan)
		Toxaphene	Rotenone
		Trichlorfon (Dipterex)	Sulphenone
		VC-13	TDE (DDD)
		Vapam	Tedradifon (Tedion)

*The fumigant compounds acrylonitrile, D-D, or Vidden D, and Telone have toxicities which would indicate their placement in the "Less Dangerous" category. However, special note should be taken of the fact that the volatility of these compounds and their capacity to produce irritation of skin, eyes, and other tissues indicate that appropriate caution should be exercised in their use.

PB 277 654



Good protection from downward spray drift is afforded by wearing a waterproof wide-brimmed hat. Lighter-colored jackets reflect more heat than dark colors.

Rubber gloves should be worn, especially when handling concentrate pesticides. Leather shoes dry out and crack with repeated exposure to spray, allowing penetration by toxic materials.

PESTICIDE PUBLICATION
621
Environmental Protection Agency
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Workers Should Be Protected From Pesticide Exposure

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EVEN THOUGH there has been some progress in recent years toward the development of pesticides that are not only low in toxicity to warm-blooded animals but also relatively nonpersistent in the environment, we should not expect such changes to be accomplished in a very short period of time.

Replacement of certain persistent so-called "hard pesticides" with compounds that are relatively nontoxic to all but the target pest is a difficult, costly, and time-consuming order. In fact, this may never be accomplished to the complete satisfaction of all concerned. Thus, for some time to come we may find it necessary to utilize compounds that are more acutely toxic to man and animals than we would eventually like to see developed.

A good example is the utilization of the more highly toxic methyl parathion as a DDT substitute in certain crop uses.

Also, a few of the new relatively nonpersistent compounds that have reached the point of registration during the last few years have acute oral LD_{50} values of less than 50, which indicates that they are highly toxic. With this in mind, we should not become lax in our concern about protection of the worker.

Even though experience has shown that more caution is warranted when working with highly toxic compounds, the need for protection from exposure to less toxic pesticides should not be ignored. Unless there is good evidence that a compound will not have any subtle adverse effects as a result of prolonged exposure, it does not seem wise to allow excess exposure even to pesticides that are considered relatively nonhazardous.

Much of the pesticide usage today involves insecticides, fungicides, and herbicides. The acute toxicity of the organophosphorus compounds that are used primarily as insecticides is, on the average, somewhat greater than that of most other types of pesticides. This class of compounds has caused many poisonings in pesticide applicators.

Most of the newer synthetic fungicides are less acutely toxic to man than other pest control compounds. However, certain fungicides may occasionally cause local irritations or dermititis.

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This light-weight unlined glove is available with enough gauntlet to protect the wrist area but flexible enough to allow freedom of finger movement. Cost is less than heavier grade gloves which are less comfortable to wear.

PROTECTION FROM EXPOSURE *(from page 12)*

Most herbicides are also generally less toxic than other types of pesticides. A dinitro compound (dinitrocresol) used for weed control for many years has caused illnesses of workers in Europe. In contrast, our exposure studies have indicated that under the conditions of use in the Pacific Northwest area of this country there is no significant hazard associated with the application of dinitro compounds for weed control. This conclusion has been corroborated by use experience.

One herbicide, paraquat, is of considerable interest because only a very small oral dose may produce irreversible lung fibrosis which usually leads to death. There is little if any response to antidotal procedures. Although many of the recorded deaths from paraquat have been due to voluntary ingestion with suicidal intent, there have been deaths following accidental ingestion of very small amounts of the liquid concentrate. In one case it was estimated that the quantity of fluid consumed could not have exceeded three quarters of a teaspoon. This compound is also somewhat caustic and may cause chemical damage to the eyes.

This emphasizes the importance of avoiding splashing the concentrate into the mouth or eyes during measuring and mixing operations.

Although illnesses resulting from overexposure to pesticide compounds do occur among applicators and other workers, most are a result of carelessness or accident. Experience has shown that if proper precautionary measures are observed and directions on the pesticide label are followed, even the more toxic compounds can be used safely.

The best insurance against illness from pesticides is to protect the various routes of entry into the body. There are three main routes: dermal, respiratory, and oral.

Dermal Route

Absorption through the skin is the most important route of entry of pesicide into the body during most exposure situations, especially where liquid sprays and emulsifiable concentrate formulations are involved. This route is one that has undoubtedly been responsible for a great many poisonings of workers, especially from the more toxic organophosphorus compounds.

We have conducted exposure studies on several hundred pesticide applicators. *Our results indicate that over 97% of the pesticide to which the body is subjected during most exposure situations, and especially to applicators of liquid sprays, is deposited on the skin.*

It should be understood that any given amount of pesticide is more rapidly and more completely absorbed by the oral or respiratory routes. However, absorption of pesticides by these two routes is probably too small a fraction of the total potential exposure to be considered the main factor in most poisoning cases of workers in the field.

Although the rate of absorption of different pesticide compounds through human skin is difficult to measure with any degree of accuracy, researchers have made some progress along that line. Using radioactive labeled pesticides, Maibach and co-workers at the University of California School of Medicine were able to determine approximately what fraction of an applied dose would be absorbed. They were not only able to compare degree of dermal absorption for certain pesticides but also they compared absorption of a single pesticide for different parts of the human body. The results obtained indicate that in the past sufficient importance may not have been attached to protection of certain body areas.

In checking dermal penetration of parathion at different body areas these researchers found that the area of greatest absorption on man is the scrotum where aproximately 100% of an applied dose was absorbed. The possibility of pesticide on this body area being completely absorbed emphasizes the need for increased concern about providing protection for the area. This is of utmost importance where spillage of highly toxic pesticides, and especially the liquid concentrate formulations, is concerned.

The head-neck area was found to be an area of greater absorption than the arms or hands.

Of particular interest was the finding that absorption in the ear canal is relatively efficient (46.6% of an applied dose of parathion). Exposure in this area could occur through drift of fine pesticide mists or dusts or by digging in the ear with the tip of a contaminated finger.

When pesticide application is by hand spray gun on target areas below waist level the area of greatest potential contamination from drift may be the lower trunk, legs, and feet. Cloth coveralls or trousers provide a reasonable amount of protection for most of these areas in work situations where contamination does not easily penetrate clothing. However, where there is chance of soaking by continued contact with liquid sprays or penetration of clothing through excessive contact with dry pesticides, waterproof trousers and boots provide the best protection. *In fact, we feel that waterproof*

footgear should be worn during most any type of pesticide application. They should be washed and dried thoroughly, inside and out, as frequently as needed to remove any contamination.

If application involves directing spray upward, the downward drift can often produce relatively high dermal and respiratory exposure. The best protection of the face-neck area from downward drift is afforded by the wearing of a waterproof wide-brimmed hat. This also reduces respiratory exposure to some extent by preventing small droplets or particles from getting near the nose where they may be drawn into the nasal orifice.

Protection of the upper trunk and arms is especially important where heavy spray drift may thoroughly wet cloth shirts, coveralls, and underclothing. A waterproof jacket or raincoat provides the best protection for this general body area.

Waterproof gear is usually worn during cooler conditions, but as the temperature rises and the clothing becomes unbearably hot to wear, workers tend to discard them and work with much less protection — perhaps only a short-sleeved, T-shirt-type undershirt.

Under such conditions workers should be encouraged to at least wear a long-sleeved cloth jacket, overalls, or tightly-woven heavy grade shirt that will not be easily penetrated by pesticide, and preferably one that can be properly washed.

Clothing should be changed and laundered daily.

If shirts, jackets, or coveralls used during application are merely hung up to dry after work and used repeatedly, as is often the practice, it doesn't take long for the pesticide material to work through where it will make contact with underclothes or skin.

Although waterproof protective clothing, and especially jackets, are often kept close at hand by pesticide applicators, it has been our observation that they usually will not put on the clothing until drift of pesticide increases to the point where they feel protection is necessary. Unfortunately, by this time there is often considerable contamination of skin and conventional clothing. *Covering contaminated skin by impermeable protective gear may create conditions which lead to increased absorption.*

Whether or not there would be less absorption under these conditions than if the protective clothing were left off entirely, depends upon the potential exposure which might occur after the worker puts on the clothing. Although the amount of increase in absorption of pesticides by covering contaminated skin with various items of protective clothing is not known, it is certainly sound advice to put on protective gear before the skin has been contaminated to any great degree.

High exposure to hands is usually the result of contact with the more concentrated formulations during mixing and loading. The hands are more subject to cuts and abrasions which allow a more direct route into the body.

This brings to attention the need for wearing gloves. Some feel it is better not to wear gloves that are somewhat contaminated on the inside; something which invariably occurs to some degree. This sounds logical; however, our research indicates that, unless there is gross contamination of the inside of the gloves, the potential exposure is less when wearing gloves than when not wearing them, regardless of a certain amount of inside contamination.

Gloves should be kept clean on the inside; thus, cloth linings are undesirable because of the difficulty in decontamination. *Unlined rubber gauntlet gloves provide the best protection.* Heavyweight gloves, although durable, do not allow adesuate freedom of movement, especially finger flexibility, and they are also difficult to turn inside-out for cleaning. On the other hand, some lightweight gloves, although flexible enough to allow freedom of finger movement, wear out rapidly and are easily torn. Therefore, it is advisable to secure gloves of a grade that is somewhat durable but yet light enough to be acceptable to the worker.

Comfort and acceptability by the worker is also important when selecting protective jackets and trousers. Heavy grade clothing is not very flexible and dark-colored materials absorb more heat. During recent years several jackets, jacket-trouser combinations, and gloves that are lighter in color and weight have been available. Although less durable, they are less costly to replace. Our tests have shown that a light yellow or white waterproof jacket may reflect enough heat to cause the temperature at the skin surface underneath to be as much as 8 to 10°F lower than when wearing a black jacket when worn under conditions of intense sunlight when ambient temperature is around 90°F. Nevertheless, there is still considerable discomfort in wearing any waterproof clothing during hot weather because of the trapping of body heat.

Disposable paper jackets have been tested and found suitable for use only under conditions where heavy wetting does not occur. Such paper jackets were found to be much cooler and thus more comfortable than other jackets tested.

Respiratory Route

Protection of the respiratory route is especially important where toxic dusts and vapors or very small spray droplets are prevalent, or where application is in confined spaces. We have found that when applying dilute sprays with conventional application equipment respiratory exposure is usually relatively low, probably due to the large droplet sizes produced. Where low volume equipment is used, smaller particles or droplets are produced, increasing respiratory exposure.

Respiratory protection for most types of outdoor application can be provided by use of cartridge-type respirators, or, in certain cases, gas mask-type respirator devices with special cannisters which have greater absorbent capacity than cartridges. Proper care of respirators is important, especially the regular replacement of filter cartridges and regular cleaning of the face-piece with soap and water. Solvents should not be used for they may damage certain parts of the respirator. When fumigating or applying highly toxic pesticides in confined spaces it is advisable to use a respirator with a special compressed air supply tank so that none of the contaminated ambient air is inhaled.

Oral Route

The most serious oral exposure may be brought about by splashing of liquid concentrate into the mouth

while pouring and measuring pesticides. Contamination may also occur through licking the lips, by rubbing the mouth with contaminated arms or hands, by careless actions such as attempting to blow out clogged spray nozzles with the mouth, or by eating, smoking, or drinking while hands are contaminated. Pesticide label precautionery statements to the effect that hands should be washed before smoking or eating is sound advice.

Discussion

Regardless of how specifically the measures for protection of workers from pesticide exposure may be stated for any particular situation, people who work with such compounds must realize that there is some element of risk involved. Accidents occur, even among workers who are careful. The importance of dermal and respiratory exposure certainly warrants the use of some type of protective gear. Improvements in protective equipment are needed to bring about better protection of workers. We at the Environmental Protection Agency, Wenatchee Research Station laboratory are continuing with studies on protective gear to determine effectiveness and acceptability. □

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PB 277 655

PROTECTION OF INDIVIDUALS WHO MIX OR APPLY PESTICIDES IN THE FIELD

PESTICIDE PUBLICATION

579

by

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Workers who mix or apply pesticides in the field are often exposed to relatively high levels of such compounds. Illnesses do occur as a result of overexposure, however, most are a result of carelessness or accident. Experience has shown that if the various routes of entry of pesticides into the body are protected, even the more toxic compounds can be used safely.

There are four routes of entry: (1) dermal, (2) respiratory, (3) oral, and (4) through cuts or abrasions in the skin. Protection of these routes prevents exposure and prevention of exposure is good insurance against poisoning.

Dermal Route: This route is probably the most important route of entry into the body during most exposure situations in the field, especially where liquid sprays are involved. The dermal route has probably been responsible for many poisonings of workers, especially from the more toxic organophosphorus compounds.

In research studies at our laboratory we have measured the potential exposure of several hundred pesticide applicators, and the results indicate that over 97% of the pesticide to which the body is subjected during most exposure situations, and especially to applicators of liquid sprays, is deposited on the skin. It should be understood that any given amount of pesticide is more rapidly and more completely absorbed by the oral or respiratory routes. However, absorption of pesticides by these two routes is probably too small a fraction of the total potential exposure to be considered the main factor in most poisoning cases of workers in the field.

In one set of experiments, for example, we have calculated the potential dermal exposure of orchard spraymen to parathion to be approximately 19 mg/hr; however, the potential respiratory exposure was calculated to be only 0.02 mr/hr of exposure.[1] This indicates that there is potentially 950 times more dermal exposure than respiratory exposure to workers in that type of application operation. Thus, if only a small fraction of the potential dermal exposure was to be completely absorbed it would probably still be more than the respiratory exposure. The respiratory route, however, takes on increased importance when exposure is to vapors, fine dusts, fogs, or aerosols made up of very small droplets.

The importance of protecting specific body areas has not been clearly defined in the past due to the difficulty in accurately measuring the degree of absorption of different compounds through human skin. The most useful and probably most accurate estimations or measurements on the percutaneous penetration of pesticides in man which have been accomplished thus far have been made by Maibach and co-workers.[2] Using radioactive labeled pesticides they were able to determine approximately what fraction of an applied dose would be absorbed through the skin. In this way they not only compared the degree of dermal absorption for certain pesticides but also compared absorption of a single pesticide for different parts of the human body. The results obtained indicate that sufficient importance may not have been attached to protection of certain body areas.

In checking dermal penetration of parathion at different body areas these researchers found that the area of greatest absorption on man is the scrotum where approximately 100% of an applied dose was absorbed. The possibility of pesticide on this body area being completely absorbed is a very important point and emphasizes the need for increased concern about protection of the area. Of utmost importance would be the need for extreme caution in order to avoid spillage of highly toxic liquid pesticide onto the scrotum.

Although cloth overalls or trousers provide a reasonable amount of protection where contamination does not easily penetrate clothing, the wearing of waterproof trousers provides the best protection for the lower trunk and leg areas and is especially recommended in work situations where there is chance of liquid spillage, soaking by continued contact with more dilute liquid sprays, or penetration of clothing through excessive contact with dry pesticides. Even though regular clothing is covered by waterproof protective gear, it is important that the worker change to freshly laundered clothing each day in order to prevent contamination of the scrotum or other skin areas. Needless to say, use of clean clothing and daily bathing in an effort to avoid excess dermal absorption are essential in any type of exposure situation.

Protection of the upper trunk and arms from contamination by toxic pesticides is important, especially under conditions where heavy spray drift may thoroughly wet cloth shirts, coveralls, and underclothing or where concentrated dry pesticides come in contact with clothing and skin. Our studies have shown that the greatest potential contamination of spraymen in this general body area is the upper back, shoulders, and forearms of workers operating equipment which propels spray up into the air where it is more subject to drift. Under these conditions a waterproof jacket or raincoat provides the best protection for this general body area. This gear is usually worn during cooler conditions, but as the temperature rises and the clothing becomes unbearably hot to wear, workers tend to discard them and work with much less protection—perhaps only a short-sleeved T-shirt-type undershirt on the upper trunk area. Under such conditions workers should be encouraged to at least wear a long-sleeved cloth jacket that will not be easily penetrated by pesticide, and preferably one that can be properly washed.

The wearing of long-sleeved heavy grade "GI" cotton shirts or coveralls as outer clothing during hot weather, often with no underclothing, is popular with many applicators even though this is not a recommended practice. Fortunately, these items of outer clothing provide a reasonable amount of protection where spray drift is light with very fine droplets that do not wet through to the skin. Under such conditions the clothing should be changed and laundered daily. If clothing used during spraying such as shirts, jackets, or coveralls are merely hung up to dry after work and used repeatedly, as is often the practice, it doesn't take long for the pesticide material to work through where it will make contact with underclothes or skin.

In selecting protective clothing for workers it is important to take into consideration the comfort of the individual when he wears such items. The conventional black or dark green rubberized or plastic waterproof jackets in common use during past years are considered by many applicators to be uncomfortable to wear not only because of greater heat absorption but also because they may be of heavy grade material and not very flexible. During recent years, however, several jackets and jacket-trouser combinations that are lighter in color and weight have been available. Although less durable, they are less costly to replace. Nevertheless, there is still considerable discomfort in wearing any waterproof clothing during hot weather because of trapping of body heat.

Disposable paper jackets have been tested and found suitable for use only under conditions where heavy wetting does not occur. Such paper jackets were found to be much cooler and thus more comfortable than other jackets tested.

Observations of pesticide applicators have indicated that although waterproof clothing items, and especially jackets, are usually carried by the worker, or readily available to him, he usually will not don the clothing until drift of pesticide increases to the point where he feels protection is necessary. Unfortunately, by this time there is often considerable contamination of skin and clothing. The covering of contaminated skin areas by waterproof clothing may create conditions under which dermal absorption may be increased. This may be more important during hot weather where high temperatures and perspiration are involved. Whether or not there would be less absorption under these conditions than if the clothing were left off entirely depends upon the potential exposure which might occur after the worker puts on the clothing. Although the increase of absorption of pesticide by covering contaminated skin with various items of protective clothing is not known, it is important to emphasize the need to put on protective gear *before* the skin has been contaminated to any great degree.

Results of the dermal absorption studies noted above indicate that the head-neck area should be given more attention. In this area absorption of parathion was found to be from 32% to 47% of an applied dose,[2] much more than we would have anticipated and more than at other areas of the body studied with the exception of the armpit and scrotum. When observing pesticide applicators it is easy to conclude that the face-neck area is less protected than most other parts of the body.

Protection from downward drift is especially important during application of liquid sprays. The headgear most commonly used by pesticide applicators is the billed cap which provides some protection for the face but very little for the remainder of the head-neck area other than the scalp. The conventional "Sou'wester" rain hat, often used when heavy downward drift occurs, does not provide exceptionally good protection for the face and sides of the neck. This is because of the narrow brim in all areas except at the back of the neck. Metal or fiber "hard hats" are also used to some extent; however, most have too narrow a brim to provide adequate protection. "Hard hats" which allow circulation of air over the head under the hat should not be used where exposure is to toxic dusts.

Our studies have shown that the greatest protection from downward drift of pesticides is afforded by some type of wide-brimmed hat, perferably made of water-repellent material. Waterproof hats, other than the "Sou'wester," were not readily available at that time. However, one is now available which is waterproof and also has a wide brim that affords good protection of the face-neck area. This type of hat should be recommended for use by all applicators who may be subjected to downward drift of pesticides.

Of particular interest in relation to exposure of the head-neck area is the finding by Maibach *et al.*[2] that absorption of parathion is relatively efficient (47% of applied dose) in the ear canal. Exposure in this area could occur through drift of fine pesticide mists or dusts or by digging in the ear with the tip of a contaminated finger.

It is of importance to note that wearing goggles and respirators provides considerable protection to the face.

Although a statement suggesting the use of goggles can be found on certain pesticide labels, they are rarely worn except by pilots who apply pesticides by aircraft. Questioning of pilots has revealed that they wear goggles not only to prevent poisoning and to keep wind out of the eyes but also to prevent certain organophosphorus pesticides that are direct inhibitors of cholinesterase from causing moisis. This is understandable because it has been shown that unilateral contamination of the eye with TEPP may cause pilots to inadequately judge distance.[3] The incoordination which may accompany this could be a serious threat to safety.

The hands are often the body area having the highest exposure to pesticides and they have a greater chance of coming in contact with the more concentrate formulations. They are also more subject to cuts or abrasions, which will be discussed later. High potential exposure to the hands brings attention to the need for wearing gloves. Some people who have worked with pesticides feel it is better not to wear gloves than to wear gloves that are contaminated on the inside; something which invariably occurs to some degree. Our research concerning the use of protective gloves indicates that, unless there is gross contamination of the inside of the gloves, the potential exposure is less when wearing gloves than when not wearing them. If gloves are kept clean on the inside there is very little doubt concerning the value of their use when handling pesticides. Unlined rubber gauntlet gloves provide the best protection because the gauntlet covers the wrist area not normally covered by the jacket sleeve and they can be turned wrong side out for proper cleansing of the unlined inside surface.

In order to provide proper protection to the feet, waterproof shoes or boots should be worn when handling or applying pesticides on a large scale. When leather shoes become wet with spray material they have a tendency to become cracked and dried out to the extent that pesticide easily penetrates through to the sock or foot. Both leather and canvas shoes absorb chemicals and may hold them in contact with the wearer. Boots should be washed and dried thoroughly, inside and out, as frequently as needed to remove any pesticide contaminant.

Entry Through Cuts or Abrasions: Any break in the skin may allow a more direct route of entry into the blood stream. Even if the outer layer of dead cells (strateum corneum) of the skin is removed by scratching or scuffing the result may be a potential for increased absorption at that site as this layer of cells is considered the main barrier against chemicals. This route of entry is one that may not have received enough attention in the past. Cuts and abrasions occur most frequently on the hands, and unfortunately, the hands are the body area most often in contact with the more concentrate forms of pesticides. There have been poisoning cases suspected as having been a result of entry by this route; however, there has not been enough evidence to definitely prove that this route played the major part in the illnesses.

One suspected poisoning case which might be used as an example involved a 25-year-old worker in a pesticide plant whose finger was crushed by a fork lift which appeared to be contaminated with concentrate parathion.[4] For several weeks prior to the accident he had been working primarily with carbaryl, along with a small amount of malathion, but nothing as toxic as parathion. The worker became severely ill and exhibited symptoms of poisoning within approximately 30 minutes of the accident, a coincidence which aroused suspicion that the illness was associated with the accident. Analysis of a blood sample showed cholinesterase activity to be very low. There was prompt clinical response to administration of atropine and 2-PAM. Although there does not appear to be enough evidence to prove entry of pesticide at the area of broken skin, the circumstances around the case indicate that this route of entry could possibly have played a major part in poisoning. In such case poisoning symptoms may not have developed had the worker been wearing gloves.

Another suspected case involved broken skin on the feet of a 54-year-old male who wore canvas shoes while spraying an apple orchard.[5] His shoes became soaked with the dilute spray from walking through wet cover crop. He had complained of "scalded feet" indicating raw, red, oozing areas especially on his soles and between his toes. On several occasions he was aided in bandaging his feet or procuring tape, etc. by co-workers. He had sprayed for several days but on the day of his death he had sprayed for 9 hours, wearing canvas shoes all day. A post-mortem blood sample showed very low cholinesterase. The physician investigating the case indicated that cause of death was parathion poisoning due to probable dermal absorption, particularly through an area of dermatitis on both feet. Because body areas other than the feet were exposed there is no complete assurance that this was the main route of entry of the compound. Nevertheless, this case points out the importance of wearing rubber boots or shoes while applying liquid pesticides.

Respiratory Route: Where toxic dusts and vapors or very small spray droplets are prevalent, or where application is in confined spaces, protection of the respiratory route is especially important. Extremely fine particles and droplets found in dusts and mists are much more easily drawn into the respiratory system than the larger droplets formed by most conventional dilute spray machines. Our tests have shown that when operating an 8X (eight times the normal dilute concentration) concentrate airblast machine in fruit orchards the potential respiratory exposure is nearly 3 times greater than when operating the conventional dilute machine.[1]

The cartridge-type respirator provides adequate respiratory protection in most types of application situations. In certain cases it is advisable to use gas masks with special canisters because of their greater adsorbent capacity. Applicator pilots who risk the possibility of flying through drift of fine droplets or dusts should use a face mask equipped with a filter canister and attached either to their belt or to the inside of the cockpit. When fumigating or applying highly toxic pesticides in confined spaces it is advisable to use a respirator with a special compressed air supply tank so that none of the contaminated ambient air is inhaled.

If respirators are to be effective they must have proper care. The rubber face-piece becomes hardened and the head straps lose their elasticity with age and exposure to heat and sunlight. These conditions lead to poor fit and allow leakage around the face-piece. Two of the more common offenses in the care of respirators that we have observed are (1) failing to occasionally wash the face-piece with soap and water and (2) neglecting to change the filter cartridges or canisters regularly. Washing of the face-piece of a cartridge-type respirator should not be attempted while the cartridges are in place as moisture may contact the activated charcoal filter material and reduce its effectiveness in adsorption and absorption of pesticides. Solvents should not be used as a cleaner for they may damage certain parts of the respirator. The general recommendation is that cartridges should be changed after 8 hours of continuous exposure. In most application situations this leaves much up to the individual worker to keep a record of his respirator exposure time. In a formulating plant where hours of exposure are more regular this is more easily controlled under the guidance of a foreman. Under conditions of intense exposure the useful life of the cartridge is much shorter. Thus, if the breathing seems hampered, or if the odor of pesticide is detected, the filter cartridges should be changed immediately. If the outer filter pads are separate removable units they should be changed more frequently than the cartridges.

During discussions of the respiratory route of entry into the body the question is often raised concerning the hazard of smoking pesticide-contaminated cigarettes. We have found it difficult to measure such potential exposure with any great degree of accuracy. The technique we have utilized thus far involves subjecting the cigarettes to normal handling through the process of removing them from the pack and placing them in the mouth, lighting them, and smoking one-half the cigarette. The remainder of the cigarette is then analyzed for pesticide content. The values obtained are based on the assumption that pesticide on the cigarette will be volatized before being broken down by burning and that none of the volatile or particulate pesticide would be trapped in the butt end of the cigarette. In observing smoking by workers it was noted that the area of greatest contamination of the cigarette was far enough from the butt end to allow burning of the contaminated area in most cases.

In studies of cigarette contamination by spraymen applying endrin in orchards, the potential exposure through smoking during application operations was calculated to be not more than 0.002 mg per cigarette, even when the cigarettes were handled with hands wet with the dilute spray.[6] In later studies[7] involving spraymen applying parathion to apple orchards by airblast machines, from 0.003 to 0.005 mg of parathion per cigarette could be recovered where they were handled with hands that were contaminated but dry. When handled with hands that were wet enough with dilute spray to leave moist spots on the cigarette paper from 0.020 to 0.050 mg could be found. In a controlled study designed to determine what might be the maximum contamination of cigarettes through such handling, hands were dipped in 45% emulsifiable concentrate parathion, the hands wiped off lightly on the trousers, and the cigarettes were handled to simulate smoking. The highest value found was 0.235 mg per cigarette.

Even though values for potential respiratory exposure through smoking contaminated cigarettes may not appear to reflect any great hazard, two important points must be kept in mind: (1) Pesticide entering by the respiratory route is practically 100% absorbed, and (2) There is no assurance that a more toxic breakdown product will not be formed and inhaled as the high temperature of a burning cigarette reaches the contaminated areas rather than complete destruction of the compound by burning. For example, in the case of parathion the oxidation product, paraoxon, is estimated to be much more toxic than the parent compound, possibly 100 to 500 times more toxic. This could be an important factor as far as hazard is concerned and emphasizes the need for recommending washing of hands and face before smoking.

Oral Route: Oral exposure is difficult to measure. We are studying techniques at the present time. Analysis of saliva samples of exposed individuals appears to give some indication of contamination. Splashing of liquid concentrate into the mouth while pouring and measuring pesticides may produce the most serious oral exposure. Contamination may also occur through licking the lips, by rubbing the mouth with contaminated arms or hands, by careless actions such as attempting to blow out clogged spray nozzles with the mouth, or by eating or drinking with contaminated hands.

We have attempted to measure the parathion contamination of typical sack lunch items, such as sandwiches, cookies, and pickles by workers whose hands had been contaminated while thinning fruit in recently sprayed apple orchards.[8] A lunch consisting of four half-sandwiches, two cookies, and one pickle was given to workers who handled and ate one-half of each item with unwashed hands. The other half of each item was analyzed for parathion. This provided potential oral exposure values for lunch items. A total of approximately 0.103 mg of parathion was found on the typical lunch mentioned above. Although this is not a great amount of pesticide, it would add to the total exposure of each individual; thus, workers should wash hands and face before eating.

Discussion: Workers who handle pesticide compounds must realize that there is some element of risk involved. Accidents do occur, even among workers who are careful. In case of accidental gross contamination of skin with a highly toxic compound every effort must be made to cleanse the contaminated area as quickly and as thoroughly as possible. The best recommendation at present is the use of plenty of soap and water. Wash by rubbing with the hands or with a piece of cloth. Do not scrub with a brush because the outer protective layer of the skin may be abraded enough to allow more rapid absorption of any pesticide not removed. A bar of soap, towel, and container of water should be carried on every pesticide application machine or accompanying vehicle for use in washing should a spillage occur. If pesticide gets in the eyes they should be thoroughly flushed with water for at least five minutes. If a person should feel ill while working with pesticides he should stop work at once and get medical attention. If his illness is diagnosed as being caused by a pesticide he should not return to work until a physician advises that it is safe to do so.

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EVALUATION OF THE HEALTH HAZARDS INVOLVED IN HOUSE-SPRAYING WITH DDT*

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SYNOPSIS

The dermal and respiratory exposure of workers during house-spraying operations has been measured to find out the main factors affecting the exposure, and, to develop effective, acceptable protective measures and clothing. Dermal exposure was found to be much greater than respiratory exposure. The major factors affecting exposure with a single concentration of formulation appeared to be spray-pump pressure, height of area being sprayed, and absorbency of surface. Temperature, type of formulation, and nozzle size had little or no effect on exposure. A plastic cape, a hard hat with a plastic visor, and rubberized gauntlet gloves gave a fully clothed man almost complete protection from dermal and respiratory exposure. A tropical helmet equipped with a plastic-netting veil is proposed for field testing. This equipment gave good protection of the shoulders, back, and chest and excellent protection of the face and neck.

Spraying the interior and parts of the exterior of dwellings and other buildings for the control of various insect vectors of disease is a common practice in many parts of the world, especially in tropical and subtropical areas. The insecticide most widely used for this purpose for some time has been DDT. However, since certain insects have become resistant to this material, other insecticides are finding a place in vector-control programmes. Some of these newer materials, such as dieldrin and diazinon, are significantly more toxic than DDT. This increased toxicity is only partially compensated for by a decreased concentration of active ingredient in the formulation. Where these more toxic insecticides are used, the hazard to the operators of spray equipment is undoubtedly increased. Cases of poisoning in public health workers using dieldrin have been reported from Venezuela, Ecuador, and Nigeria (Hayes, 1957), and also from India (Patel & Rao, 1958; Rahman, Singh & Datta, 1958).

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Although the exposure factors involved in the outdoor application of various toxic spray materials both for agricultural and for public health purposes have been studied extensively (Batchelor & Walker, 1954; Batchelor, Walker & Elliott, 1956; Culver, Caplan & Batchelor, 1956; Hayes et al., 1957), little research has been directed towards evaluating the hazards involved in the spraying of houses. The desirability of making such studies has been pointed out by Barnes (1957).[1]

The present paper presents the results of studies to determine the dermal and respiratory exposure of workers during indoor and outdoor spray operations, to find out the main factors affecting the exposure, and to develop effective, acceptable protective measures and clothing. Although this work was carried out using DDT only, the results should be applicable, at least qualitatively, to other insecticides which are used in a similar manner.

Materials and Methods

The indoor exposure tests were done in a small, single-room dwelling, typical of the housing provided for itinerant orchard workers in the Wenatchee Valley Area of Washington. In regard to size, this house would probably be representative of the type of dwelling sprayed for vector control throughout the world. The room measured 8 feet by 12 feet (2.4 m × 3.7 m) with walls 6 feet (1.8 m) high. The ceiling, which was the underside of the pitched roof, was 6 feet high at the wall and sloped up to 9 feet (2.7 m) at the apex. All surfaces were smooth and painted. In the room during the experiment were a small cooking-stove, an ice-box, a sink, and a waist-high cupboard along one wall.

The sprayer used was a cylindrical, compressed-air, hand-operated type, of capacity 3.5 US gallons (about 13 litres), equipped with a 20-inch (50-cm) wand. Two different nozzles were used in various tests. Both produced fan-type spray patterns, one size 50-0.15 and the other 80-0.20. (The first number refers to the angle subtended by the fan pattern and the second number to the rate of discharge, in gallons per minute, at 40 pounds per square inch (p.s.i.) pressure (2.8 atm.).) A pressure gauge was attached to the spray tank. Except where noted, all tests were conducted at an average pressure of 40 p.s.i. All the spraying involved in this study was performed by one of the authors (H.R.W.) in order to minimize variations in the technique of spraying. The same procedure was followed during each spraying cycle; the wand was held approximately 15-18 inches (38-45 cm) from the surface being sprayed, and the spraying was accurately timed by means of a stop-watch. In all the spraying, including that of the ceiling, the operator stood as far as possible out of the spray drift. The walls and ceiling

[1] An excellent study has recently been carried out by Fletcher, Press & Bagster Wilson (see article on page 15 of this number of the *Bulletin*).

were sprayed at a rate necessary to obtain a deposit of 200 mg of DDT per square foot (about 2 g per m^2) when using the 50-0.15 nozzle at a pressure of 40 p.s.i. The same time schedule was used with the 80-0.20 nozzle. With this larger nozzle, a somewhat greater deposit was obtained. Each spraying cycle consisted in spraying the interior of the dwelling twice, giving a total exposure time of 6 minutes. Two-thirds of the spraying time was required for the walls and one-third for the ceiling. The pump pressure for a spraying cycle is given as the average p.s.i. The pressure was regulated by pumping the sprayer a predetermined number of p.s.i. above the pressure desired, so that during the cycle the pressure would drop the same number of p.s.i. below, and the desired test pressure would thus be averaged.

Two different formulations of 5% DDT in water were sprayed: an emulsion made from a 25% emulsifiable concentrate and a suspension prepared from a 75% water-dispersible powder.

The potential dermal exposure was estimated by attaching absorbent pads to various parts of the operator's body or clothing, and allowing them to be exposed during a spraying cycle. The technique was essentially that described by Batchelor & Walker (1954) and by Batchelor, Walker & Elliott (1956). The pads were placed on the tops of the right and left shoulders, the back, the upper chest near the jugular notch, the back of the forearms and neck, the front of the thighs, and over the nose and mouth when the respirator was not being used. For measuring potential respiratory exposure, a single-unit respirator containing a filter-pad was worn. A plastic funnel was inverted over the filter-pad holder and taped securely. The funnel tip was cut off and the hole plugged. On the under surface two openings, each 12 mm in diameter, were cut. The respirator was modified in this way in order to prevent impingement of spray drift on to the respirator pad, and to simulate more closely the position of the nasal orifices.

In the laboratory, a 2-inch (5-cm) square section cut from the centre of each dermal exposure pad or the entire respirator pad was extracted in a Soxhlet apparatus. The DDT content of the extract was determined by a modification of the Schechter-Haller procedure (Communicable Disease Center, 1953). Results were converted to milligrams of DDT deposit per square foot per hour of exposure. During the course of this study, 1404 dermal and 113 respirator pads were analysed.

Air samples were collected using the procedure described by Batchelor & Walker (1954). The DDT content was determined by the method cited above.

DDA in urine was determined by the method described by Cueto, Barnes & Mattson (1956).

The protective clothing studied is illustrated in Fig. 1-4. The only newly introduced item is the veil, which is made from 20×20 mesh plastic netting of a dark green colour. A finer mesh interferes too much with vision and a coarser mesh offers less protection. A light-coloured mesh is not

satisfactory because it reflects light and thus interferes with vision. A number of patterns were tried. Making the side pieces wider in an effort to cover the shoulders merely caused the veil to rub the shoulders, and thus led to discomfort and occasionally to a shifting of the hat on the head. A full-size pattern for a satisfactory veil can be made easily by reference to the 1-inch grid shown in Fig. 4. The back piece of the veil should be sewn to the sides using an overlap seam (see diagram in Fig. 4). The veil should then be fitted over the hat with which it is to be used. It will be found that the netting stretches and permits a snug fit on the hat. The next step is to take up the front seams with pins to determine the proper width of seam. The width should be such that the front of the veil will hang parallel to the front of the face or even slope in slightly at the bottom. After this fitting has been done for one hat and the proper amount of overlap of the front seams determined, it should be possible to make veils for identical hats without additional fitting. After the seams have been sewn, they should be reinforced with pre-shrunk bias tape. Bias tape should also be stitched around the lower edge of the veil, but not around the top margin. Masking-tape is the best material for fastening the veil to the hat. It is easy to remove or replace. Stiffeners made of steel wire (about 3/32 inch (2.4 mm) in diameter) may be used to hold the front piece of the veil straight, but they are not essential. It is desirable to stiffen the front lower edge of the veil with one or two strips of masking-tape.

A small, one-roomed house, similar to that described for the indoor tests, was used in the outdoor studies. The surfaces sprayed included the upper part of the walls and the under side of the eaves. The same sprayer was used both outdoors and indoors.

Results

Exposure under usual conditions

To provide an estimate of exposure of workers under the conditions most often prevalent in indoor spraying operations, measurements were carried out during the use of a 5% DDT suspension, made from a 75% water-dispersible powder, with an 80-0.20 nozzle at an average pressure of 40 p.s.i. The exposure values determined under these conditions for various body areas are shown in Table 1. The area of highest exposure was found to be the right arm and hand. In right-handed persons this is the hand which holds the spray wand and is, therefore, nearest the spray. This exposure is about three times that for the right shoulder, which received the next highest dose. In all preliminary tests the exposure on the lower legs was found to be negligible ; therefore, measurements of exposure in this area were not continued throughout the experiment. From these data it appears that the main exposure from indoor surface spraying is on the upper trunk

TABLE 1. EXPOSURE TO DDT DURING INDOOR AND OUTDOOR SPRAYING OPERATIONS *

Variable studied		Number of replicates	Average exposure (mg/square foot/hour)										
			Right shoulder	Left shoulder	Back	Chest	Right arm	Left arm	Right thigh	Left thigh	Face	Back of neck	Total
Exposure under usual conditions		4	410	145	86	250	1497	35	36	8	41	15	2523
Pressure	20 p.s.i. (1.4 atm.)	4	29	35	7	25	118	18	12	< 5	—	< 6	< 255
	30 " (2.1 ")	4	92	70	11	33	438	14	11	< 10	—	< 4	< 719
	40 " (2.8 ")	4	289	126	51	112	993	32	18	< 4	—	14	< 1639
	50 " (3.5 ")	4	576	168	58	305	1524	69	33	4	—	22	2759
Height of surface	Walls	8	16	20	8	7	28	9	6	3	4	4	105
	Ceiling	8	1106	242	148	230	2632	161	94	27	133	36	4807
Type of surface	Smooth	4	592	132	118	200	1475	65	58	12	54	34	2749
	Heavy residue	2	137	49	30	88	462	11	20	30	14	11	852
	Roughed-up fibreboard	4	24	19	9	18	132	12	4	7	< 2	4	< 231
Temperature	34-38°F (1-3°C)	4	39	10	10	30	201	7	5	1	9	3	< 315
	58-90°F (14-32°C)	4	108	36	28	36	491	33	10	4	14	6	766
Formulation	Water-dispersible powder	4	410	145	86	250	1497	35	36	8	41	15	2523
	Emulsion	4	289	126	51	112	993	32	18	< 4	—	14	< 1639
Nozzle size	50-0.15	4	592	132	118	209	1475	65	58	12	54	34	2749
	80-0.20	4	289	126	51	112	993	32	18	< 4	—	14	< 1639
Protective clothing	None	13	410	110	62	158	1094	37	44	10	46	18	1989
	Cape, type 1	4	< 2	< 2	< 3	< 3	< 2	< 2	7	6	—	—	< 27
	Cape, type 2	4	4	< 2	56	< 2	921	44	20	< 4	—	—	< 1053
	Hat, plastic visor	4	91	46	24	18	—	—	—	—	< 2	< 2	< 183
	Hard hat only	12	276	111	47	113	—	—	—	—	80	< 4	< 631
	Hat, 20 × 20 visor	8	276	90	47	57	—	—	—	—	18	< 6	< 494
	Hat, 28 × 28 visor	8	352	124	57	83	—	—	—	—	18	< 4	< 638
	Helmet, veil	12	26	32	8	22	—	—	—	—	< 7	< 2	< 97
Exposure during outdoor spraying		4	84	71	31	60	170	28	22	16	15	4	501

* Unless otherwise noted, indoor spraying was carried out at a temperature of 36-65°F (2-18°C) and at an average pump pressure of 40 p.s.i.

TABLE 2. DERMAL EXPOSURE TO DDT PER HOUR OF INDOOR SPRAYING *

Unclothed body part	Location of pads	Body area (square feet**)	Pad recovery (mg/square foot/hour) †	Total calculated exposure (mg/body part/hour)
Face	Face	0.70	41	29
Right side of head	Face	0.18	41	7
Left side of head	Face	0.18	41	7
Back of neck	Back of neck	0.12	15	2
Front of neck and "V" of chest	"V" of chest	0.16	250	40
Right forearm and right hand	Right forearm	1.09	1497	1632
Left forearm and left hand	Left forearm	1.09	35	38
Total		3.52		1755

* Calculated on the basis of an operator wearing a short-sleeved, open-necked shirt and no gloves. The spraying was carried out with a 5% DDT suspension at an average pump pressure of 40 p.s.i.

** 1 square foot $\simeq$ 0.1 m^2

† 1 mg per square foot $\simeq$ 10 mg per m^2

and upper extremities. (It is important to note, however, that the feet and lower legs of some members of spray teams become grossly contaminated. The cause of this observed variation is not known.)

Assuming that the operator wears a shirt with short sleeves and an open collar, that he wears no hat or gloves, and that his clothing gives complete protection to the area covered, it can be calculated from the above data that his dermal exposure would be about 1755 mg of DDT per hour of spraying. These calculations are summarized in Table 2.

The average respiratory exposure, based on absorption of DDT by respirator pads, was found to be about 7.1 mg per hour of spraying. This very low value in comparison with dermal exposure is similar to the results reported for outdoor spraying of parathion (Batchelor & Walker, 1954) and of dinitro-orthocresol (Batchelor, Walker & Elliott, 1956) for agricultural purposes.

Air samples taken in the breathing zone of the operator under these basic conditions of indoor surface spraying were found to contain 7.1 mg of DDT per m^3. This level exceeds the 1 mg per m^3 value which has been set by the American Conference of Governmental Industrial Hygienists (1957) as the maximum level to which workers should be exposed for an 8-hour working-day.

The figure for respiratory DDT exposure calculated from respirator-pad values has been compared with the respiratory-exposure figure calcu-

lated from air-concentration values. Assuming a tidal air volume of 480 litres per hour, it may be calculated that the inhalation of DDT is 3.4 mg per hour. This figure is of approximately the same order of magnitude as the 7.1 mg per hour value based on the respirator pads.

Using the values given above, it can be calculated that the total potential exposure for a spray operator under these conditions would be about 105 mg/kg for a day's work, assuming that the worker was actually spraying for 4 hours out of his 8-hour working-day. This figure may be compared to the acute dermal LD_{50} value of 2510 mg/kg for dissolved DDT in white rats. Rats are usually able to withstand repeated daily dermal dissolved doses of 100 mg/kg, but are usually killed by 200 mg/kg under these conditions (Hayes, 1959). Hayes, Durham & Cueto (1956) have reported a study in which men were fed DDT at the daily rate of 35 mg per man (0.5 mg/kg) for periods of up to two years. During this entire study, no volunteer complained of any symptom or showed, by the tests used, any sign of illness that did not have an easily recognized cause, clearly unrelated to exposure to DDT.

Effect of various factors on exposure

A number of factors, some of which could be modified under practical field conditions and others of which would be fixed, were studied to determine their effect on exposure. These factors include the following:

(*a*) *Spray-pump pressure.* Since it is common practice in the field to pump sprayers up to 50 or 55 p.s.i. and then spray until the pressure falls to about 20 p.s.i., comparative studies were made of exposure at pressures of 20, 30, 40 and 50 p.s.i. (1.4, 2.1, 2.8, and 3.5 atm.). The results of this work are shown in Table 1. It will be noted that for each 10 p.s.i. (0.7 atm.) increase in pressure the dermal exposure increased by a factor of between 2 and 3. At 50 p.s.i. the exposure was about 11 times as great as that at 20 p.s.i. Respiratory exposure was about 1 mg per hour of spraying at 20 and 30 p.s.i., 3 mg at 40 p.s.i., and 6 mg at 50 p.s.i. A longer time is required to deliver a given volume of spray at a low pressure than at a high pressure. However, the time taken to spray at 20 p.s.i. is less than twice that taken at 50 p.s.i. Thus, there is a significant decrease in the exposure of the operator at low spraying pressures, even if the comparison is based on a standard rate of deposit per unit area.

Since higher pressures give increased dermal and respiratory exposures, the lowest pressure that gives a suitable spray pattern and surface coverage would seem to be the most desirable from the standpoint of the health hazard to spray operators. At 20 p.s.i. the spray pattern was slightly uneven. At 30 p.s.i., however, the pattern appeared to be even and the rate of discharge was great enough to allow surface coverage with 200 mg of DDT per square foot at a reasonable speed.

(*b*) *Height of area sprayed.* It was apparent from visual observation of indoor spraying that exposure of the operator was greatest while he sprayed surfaces above his head. A comparison of exposure during wall-spraying with exposure during ceiling-spraying is made in Table 1. The measurement confirmed the visual observation that spraying the ceiling resulted in much greater exposure than spraying the walls. In the dwelling under study, in which the ceiling surface was only about one-third as great as the wall surface, over 97% of the total exposure during a spraying cycle occurred while the ceiling was being sprayed.

In contrast to the exposure values determined under the usual conditions for complete spraying cycles, the exposure on the right-arm area was only slightly greater than that on the shoulder area when only the walls were sprayed. Also, during wall-spraying, the exposure on the left shoulder, instead of being considerably less, was slightly greater than that on the right shoulder, and exposure on the neck and face was very low. The ratio of the exposure values for the various body areas was approximately the same for ceiling-spraying as for spraying the complete room.

If a spraying operation should involve overhead spraying only, it is possible for the operator to receive several times as much exposure per unit time as he would when spraying both walls and ceiling.

(*c*) *Type of surface.* A study of the effect of the type of surface on exposure was of interest because various surfaces, ranging from smooth, painted wood to rough or absorbent surfaces of mud and thatch, are encountered in the field.

One variation in surface was produced by spraying the room several times without cleaning the walls or ceiling, so that a heavy residual deposit was built up. The effect of this change in surface was to decrease the exposure of the operator to about one-third its value in the case of the smooth, painted surface.

Other tests were carried out in which the ceiling was covered with absorbent fibreboard which had been roughened by scratching with a sharp implement until many bits of fibreboard protruded ¼ to ½ inch from the surface. This type of surface produced a still larger decrease in exposure. The exposure resulting from spraying the entire room with fibreboard on the ceiling was less than 10% of the exposure resulting from spraying the room's painted surfaces.

(*d*) *Temperature.* Comparative studies made at two different temperature ranges indicate that exposure is increased when spraying is carried out at higher temperatures. The exposure was approximately twice as great at the high temperature-range studied—58-90° F (14-32° C)—as at the low range—34-38°F (1-3°C). The detailed results are not shown in Table 1, since not enough replications were involved to make the results significant, but small increases in exposure were found with each temperature incre-

ment. All the tests involving variation in temperature were carried out using the DDT emulsion prepared from the emulsifiable concentrate. It may be that the increased exposure at the higher temperature is associated with an increased volatilization of the xylene vehicle and a consequent reduction in the size and mass but not in the velocity of the spray particles.

(*e*) *Formulation.* A slightly greater dermal and respiratory exposure was found when using a suspension prepared from water-dispersible powder than when using an emulsion prepared from emulsifiable concentrate.

The concentration of DDT in the air was also found to be somewhat higher when the water-dispersible powder formulation was used. On the other hand, the operator commented repeatedly on the discomfort caused by spraying indoors with the emulsion. Spraying with this formulation burned his eyes and caused him to become nauseated. These effects were more pronounced at higher temperatures and may be attributed to the solvent. There was no discomfort associated with spraying the suspension prepared from the water-dispersible powder.

(*f*) *Spray-nozzle size.* There appeared to be no appreciable difference in dermal exposure when comparing the 50-0.15 nozzle with the 80-0.20 nozzle. From visual observation it appeared that, particularly at higher pump pressures, the 80-0.20 nozzle broke the spray into smaller droplets that seemed to " hang " in the air for a longer period of time. It was expected, therefore, that the suspended particles would cause a greater general exposure with the 80-0.20 nozzle. The quantitative study failed to corroborate the visual observation in the case of dermal exposure, but respiratory exposure, which is favoured by small particles, did appear to be higher with the 80-0.20 nozzle (4.5 mg/hour) than with the 50-0.15 nozzle (2.3 mg/hour).

Efficiency of various types of protective clothing in preventing exposure

Some of the various types of protective clothing studied are illustrated in Fig. 1-4. Capes, types 1 and 2, and the hard hat with plastic visor (see Fig. 1 and 2) have previously been proposed for use and have had field trial.

It appeared that ordinary cotton clothing gave almost complete protection to the body area covered. All values for exposure under cotton clothing in four replicated tests were below the experimental limit of the analytical method. It should be noted, however, that the spraying time involved in these tests (24 minutes) was not sufficiently long to wet the cotton garments with the spray. Undoubtedly, the protective effect of these garments is limited by the capacity of the fabric to absorb the spray. However, wetting does not usually occur if spraying is done carefully because the small amount of liquid evaporates as rapidly as it is deposited. These

FIG. 1. TYPE-1 CAPE AND HARD HAT WITH PLASTIC VISOR, SIDE VIEW

Note the almost complete coverage afforded the arms by this cape. Gloves would ordinarily be used with this equipment.

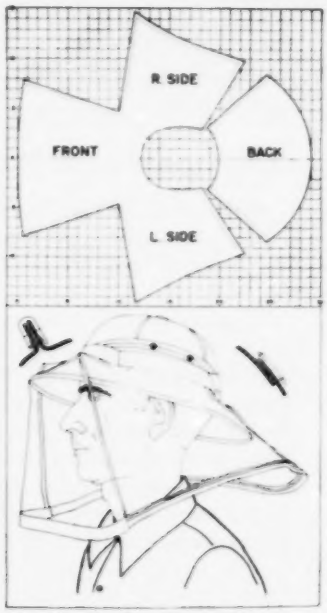
FIG. 2. TYPE-2 CAPE, HARD HAT WITH PLASTIC VISOR, AND RUBBERIZED GAUNTLET GLOVES, SIDE VIEW

Note exposure of arms with this cape and also exposed neck-shoulder area due to displacement of cape by shoulder strap of sprayer.

FIG. 3. TROPICAL HELMET WITH PLASTIC-NETTING VEIL AND RUBBERIZED GAUNTLET GLOVES, FRONT VIEW

Note coverage afforded to neck, shoulder, upper back, and upper chest areas as well as to face by this veil.

FIG. 4. PATTERN AND DRAWING OF PLASTIC-NETTING VEIL (SHOWING TAPE ATTACHMENT TO TROPICAL HELMET)



The diagrams indicate details of the front and back seams and the bias tape used to reinforce them.

results are similar to those reported by Hayes (1959), who found that wearing a cotton shirt reduced skin contamination from 1200 mg/m² to 5 mg/m².

As can be seen from Table 1, the type-1 cape gave almost complete (about 98%) protection from the neck down, whereas the type-2 cape gave only about 50% protection. The primary difference between these two capes with regard to protective effect lay in the greater shielding afforded the arms by type 1.

The hard hat with plastic visor gave almost complete protection to the face and neck and this combination, as well as the hard hat alone, also gave some protection to the shoulders, back, and chest. Almost complete protection of significantly exposed body areas may be achieved by wearing the type-1 cape and the hard hat with plastic visor.

It is difficult to enlist the co-operation of spray-men in the wearing of protective clothing which is heavy or which adds to their discomfort in tropical areas by preventing free circulation of air. Capes, type 1 and type 2, and the hard hat with plastic visor suffer from both these disadvantages. In addition, it is difficult, owing to the fastening of the cape at the wrists, to get the sprayer over the shoulder with the type-1 cape. With the shoulder pads now used in the type-2 cape, the sprayer strap tends to pull the cape in one direction or the other, with the result that a larger than necessary area of the neck, shoulders, and chest is exposed to possible dermal contamination. A further disadvantage of the plastic visor is that it quickly becomes coated with residue and vision is seriously interfered with, particularly in subdued light. After a short period of spraying the plastic visor becomes so coated that it is impossible to see through it at all. This deposit is not easily removed with water, but can be removed by means of an organic solvent.

In an attempt to develop more acceptable protective clothing, a visor cut from 20×20 mesh plastic netting was used with the hard hat. This modification was lighter and cooler than the hard hat equipped with plastic visor, but gave little better protection than the hard hat alone, except around the mouth and nose. Results with a visor cut from 28×28 mesh plastic netting were similar.

Another modification tested was the use of a tropical helmet equipped with a plastic-netting veil (Fig. 3 and 4). The tropical helmet with such a veil should be acceptable to the spray-men, since it is a combination that offers little interference to circulation of air and is considerably lighter in weight (255 g) than the hard hat with plastic visor (670 g). Spray droplets or dried residue deposits which collect on the veil interfere little with vision. The veil requires cleaning less often and is more easily cleaned than the plastic visor.

It can be seen from Table 1 that the tropical helmet with veil gave excellent protection of the shoulders, back, and chest and almost complete

TABLE 3. PROTECTION AFFORDED BY TROPICAL HELMET AND VEIL TO VARIOUS BODY AREAS DURING INDOOR SPRAYING OF DDT

Body area	Protective effect (%) *		
	using 80-0.20 nozzle and water-dispersible powder	using 50-0.15 nozzle and emulsifiable concentrate	mean
Right shoulder	76	84	80
Left shoulder	27	71	49
Back	68	87	77
Chest	64	86	75
Face	46	87	67
Back of neck	53	89	71
Respiratory	—	31	31

$$\text{* Protective effect (\%)} = \frac{\text{(unprotected value} - \text{protected value)}}{\text{unprotected value}} \times 100$$

protection of the face and neck. The percentage protection afforded to various body areas by this equipment is shown in detail in Table 3.

Other measurements of exposure

As noted above, all the indoor spraying reported in this paper was carried out by the same person. During a period of 6 months, this man sprayed the test building inside 309 times, using a total volume of 123 US gallons (465 litres) of 5% DDT spray representing 46 pounds (about 20 kg) of actual DDT. He spent about 15.5 hours actually spraying. Twice during this period tests of his urine for DDA content were carried out, at times when it was felt that his exposure was likely to have been maximal. On both occasions his urinary DDA content was below the limit of sensitivity of the experimental method. Previous work has indicated that absorption of oral dosages of DDT as low as 3.5 mg per day will result in the excretion of measurable quantities of DDA in the urine. (Obviously, the implications of this study of excretion are limited to DDT. It is known that some other compounds are absorbed by the skin in significant and even toxic quantities under field conditions.)

Exposure during outdoor spraying

For comparative purposes, measurements were made of dermal and respiratory exposure to DDT during simulated outdoor surface spraying activities for control of insect vectors of disease. The results of this work are shown in Table 1. The total dermal exposure during outdoor spraying,

calculated in the way shown in Table 2, was 243 mg/hour and, therefore, considerably less than that during indoor spraying (1755 mg/hour). The respiratory exposure was very much less outdoors (0.11 mg/hour) than indoors (7.1 mg/hour). The order of comparative exposure for various body areas during outdoor spraying was similar to that found indoors.

One might expect a somewhat greater variation in exposure between different outdoor spraying cycles, since, out of doors, one has much less control over wind and temperature. However, in the present study, the inter-cycle variations were similar outdoors and indoors. This similarity is probably explained by the fact that there was little variation in wind or temperature during the days on which the outdoor tests were conducted.

Discussion

The studies reported in this paper indicate that, of the clothing tested, the type-1 cape and hard hat with plastic visor together afford the best protection during indoor spraying. The spray-man should wear rubberized gauntlet gloves to protect his hands during mixing and filling as well as during actual spraying operations. This combination of protective equipment (type-1 cape, hard hat with plastic visor, and rubberized gauntlet gloves) should give almost complete protection from both dermal and respiratory exposure to a spray-man wearing a long-sleeved shirt, long trousers, and shoes.

The important features of the spray-man's hat include a wide brim and a waterproof surface. Hats of local manufacture may be entirely satisfactory and much cheaper than the ones shown in the figures.

In view of the possible non-acceptance by field personnel of the protective clothing listed above, consideration should be given to field trials of the combination of tropical helmet and veil described. When worn with other appropriate clothing, the wide-brimmed, waterproof hat and veil should give quite satisfactory protection against both dermal and respiratory contamination. Calculations similar to those summarized in Table 2 indicate that these protective devices (long-sleeved shirt, long trousers, shoes, rubberized gauntlet gloves, and tropical helmet and veil) would decrease potential exposure almost to zero (less than 2% of unprotected value). It should be noted that this protection is better than that shown in Table 3, which includes the effect of the tropical helmet and veil only. In addition, the spray-man can further reduce his exposure by using the lowest spray-pump pressure consistent with an acceptable spray pattern and adequate surface coverage. It is probably not necessary to mention more obvious safety practices such as standing as far as possible out of the spray drift, especially when spraying overhead surfaces. The importance of washing hands and face before eating or smoking, of a daily bath with soap and water, and of the daily washing of contaminated clothing also should be strongly emphasized.

RÉSUMÉ

Les dangers d'intoxication encourus par les opérateurs chargés de pulvériser des insecticides en plein air pour lutter contre les ennemis des cultures ou les vecteurs de maladies ont été bien étudiés. Ceux qui menacent les techniciens opérant à l'intérieur des habitations ont été moins exactement évalués.

Les auteurs ont mesuré la quantité de DDT à laquelle est exposé un opérateur dans un local de $2{,}5 \times 4 \times 2$ m environ, soit par contact, soit par inhalation. Ils décrivent la protection vestimentaire à recommander à un opérateur portant une chemise à manches longues, un pantalon long et des chaussures. cape, chapeau imperméable à larges bords rigides, avec masque en plastic, gants à manchettes caoutchoutés. Le casque tropical avec voile peut remplacer le chapeau à bords rigides et le masque. L'opérateur peut encore diminuer les risques, en limitant la pression du pulvérisateur au minimum compatible avec l'efficacité requise. Une hygiène personnelle est en outre à recommander: lavage des mains et du visage avant de manger ou de fumer, bain quotidien avec savonnage, lessivage quotidien des vêtements souillés.

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PESTICIDE PUBLICATION

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Hazards of Equipment Contaminated With Parathion

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The persistence of dangerous quantities of organic phosphorus insecticides in apparently empty containers has been well recognized as a cause of poisoning, particularly in children.[1] Recognition of similar hazards from equipment previously used for insecticidal application has received less attention in the literature. The occurrence, in less than three weeks, of three cases of nonfatal poisoning due to this type of exposure in Phoenix, Ariz, has emphasized the danger of working with contaminated equipment and prompted this report.

Report of Cases

CASE 1.—A 36-year-old insecticide loader was hospitalized because of nausea and vomiting of one day's duration. He had loaded parathion four days previously but had had no known exposure to organic phosphorus compounds since that time. About 28 hours before admission he had washed a plane which previously had been used for insecticidal application, and two hours after this work, dizziness, nausea, diaphoresis, and blurring of vision were noted. These symptoms persisted overnight in association with orthopnea, restlessness, and insomnia. Symptoms continued for almost 24 hours before he was hospitalized and treated with intramuscular atropine. He had begun to improve at the time of hospitalization, but his improvement was accelerated by the administration of atropine.

CASE 2.—A 30-year-old crop duster was hospitalized because of dizziness, nausea, and vomiting which occurred shortly after he had dismantled the hopper of his airplane. Although in previous months the plane had been used for applying large quantities of parathion, only magnesium chlorate, a defoliant, had been used during the previous two weeks. About 30 minutes after dismantling the hopper, the patient felt lightheaded and began perspiring profusely. Later, he became nauseated, vomited several times, and complained of numbness and tingling of his hands. There was no miosis.

TABLE 1.—*Laboratory Data: Case 1: Cholinesterase Activity (Δ pH Units/Hr): RBC 0.05*; Plasma 0.00*; Urinary p-Nitrophenol†*

Specimen No.	No. Hr Since Exposure	p-Nitrophenol, PPM	Parathion Equivalent μg/Hr
1	28	0.60	—
2	32	0.90	76
3	34	0.76	126
4	37	0.65	64
5	44	0.64	20
6	47	0.56	46

* Normal mean and standard deviation for this laboratory are 0.82 ± 0.09 for red cells and 0.78 ± 0.19 for plasma.

† Metabolite of parathion, methyl parathion, and ethyl *p*-nitrophenyl thionobenzenephosphate (EPN). (references 2-4).

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TABLE 2.—*Laboratory Data: Case 2: Cholinesterase Activity (Δ pH units/hr): RBC 0.05; Plasma 0.00; Urinary p-Nitrophenol*

Specimen No.	No. Hr Since Exposure	p-Nitrophenol, PPM	Parathion Equivalent, μg/Hr
1	10	3.97	98
2	24	1.25	58

TABLE 3.—*Laboratory Data: Case 3: Cholinesterase Activity (Δ pH units/hr): RBC 0.23; Plasma 0.05; Urinary p-Nitrophenol*

Specimen No.	No. Hr Since Exposure	p-Nitrophenol, PPM	Parathion Equivalent, μg/Hr
1	14	3.09	—
2	17.5	7.58	162

Symptomatic relief rapidly followed the institution of atropine therapy.

CASE 3.—A 21-year-old male with no known exposure to organic phosphorus insecticides during the previous week was hospitalized because of nausea and vomiting of six hours' duration. On the day of his illness, he had washed three airplanes that previously had been used extensively for application of parathion. The planes had been washed once since the last application of parathion and had been used exclusively for non-organophosphorus defoliants during the previous week. A few hours after washing the planes, the patient complained of nausea, vomiting, dizziness, and blurring of vision; miosis was noted. He was taken immediately to the hospital where treatment with intramuscular atropine and intravenous fluids rapidly relieved his symptoms.

Comment

Although many insecticides in common use are highly toxic, most authorities feel that all of them are safe if handled properly. However, despite the abundant literature describing precautions necessary for safe occupational use of organic phosphorus compounds,[5-7] little attention has been directed to the dangers associated with the use of contaminated equipment. This hazard would appear to be related to the insecticide that contaminates the equipment. Compounds such as tetraethyl pyrophosphate (TEPP), 2-carbomethoxy-1-methylvinyldimethyl phosphate (Phosdrin), and dimethyldichlorovinyl phosphate (DDVP) hydrolyze completely or dissipate as a gas in a matter of hours at 25 C, while a more stable compound such as parathion[7] has a half-life of 120 days at 25 C. It has been demonstrated that lethal quantities of parathion have persisted in allegedly empty metal containers left in open fields for periods up to a year,[8] and it is not illogical to assume that equipment used for mixing or applying insecticides remains similarly contaminated.

The three cases described above were unequivocal cases of organophosphorus poisoning in which the only apparent source of exposure was equipment (planes) which had previously been used for insecticidal application and which had not been adequately decontaminated. That parathion was the compound causing symptoms is indicated by the presence of large quantities of *p*-nitrophenol (a specific urinary metabolite of parathion) in the urine of each person and by the fact that parathion was used far more than other organophosphorus compounds in the Phoenix area during the months preceding these illnesses.

The first patient was decontaminating planes at the time of his exposure but was using minimal safety precautions. A fatal case of poisoning of a swamper who had washed a plane used for application of the organophosphorus compound O-O-diethyl O-[2-(ethylthio)ethyl]-phosphorothionate (Demeton) has been reported from California.[9] The patient described in case 2 had dismantled the hopper of his duster in order to steam clean it. Although he was generally cautious in handling organophosphorus compounds, he had assumed that the hazard of poisoning had been obviated by the long period of time since organophosphorus compounds had been used. The plane that probably provided the exposure for the third patient had been washed with water one week previously and no organophosphorus

compounds had been carried in it since that time. Careful questioning revealed that, in contrast to the previous cleaning, an effort was made on the day of the poisoning to wash the undersurface of the plane. It is not unlikely that some of the relatively insoluble parathion [10] had remained on the entire plane surface and that the undersurface remained particularly heavily contaminated during the period between washings. The knowledge that the plane had previously been washed probably permitted a complacent attitude toward the danger of poisoning.

The obvious conclusion from study of these cases requires little comment. All equipment that has been used for organophosphorus insecticides, particularly compounds that are relatively stable such as parathion, must be considered contaminated and dangerous until thorough decontamination procedures have been performed. Information is lacking on the relative stability of organophosphorus compounds in situations such as on aircraft wings and ground surfaces exposed to the environment and in relatively protected situations, ie, interiors of tanks, hoppers, and aircraft fuselage. However, it is known that under conditions of high moisture tension and elevated temperature compounds such as parathion and malathion are oxidized to more toxic materials. Therefore, employees whose duties involve maintaining or cleaning such equipment must be informed of the hazards involved and instructed to follow safety procedures identical with those for handling the toxic insecticides themselves. Similarly, planes, spray rigs, and other equipment must be kept in areas that are forbidden to persons with no knowledge of the hazards of insecticidal exposure.

Lastly, it is important that physicians seeing patients with illnesses suggesting organophosphorus poisoning, in which a source of exposure is not obvious, should investigate the possibility of exposure from contaminated equipment.

Summary

Three cases of organophosphorus poisoning in which the source of exposure precipitating the illnesses appeared to be airplanes contaminated with insecticides were seen in a period of three weeks. This experience emphasizes the fact that all equipment used for application or handling of toxic insecticides, particularly the relatively stable ones such as parathion, should be considered dangerous until thorough decontamination procedures have been carried out.

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PESTICIDES PROGRAM
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SAFETY PRECAUTIONS RELATED TO PESTICIDE USE

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Man is often subjected to relatively high levels of pesticide compounds when he is actively engaged in pest control operations. Since most chemical pesticides have at least some degree of toxicity to man, anyone who works in pest control should be aware of any potential hazard that can accompany the use of such compounds. Well-informed workers are more likely to take proper precautionary measures in handling toxic materials and these persons play an important part in maintaining a good safety record for pesticide usage.

Experience has shown that if proper precautionary measures are observed and directions on the pesticide label are followed, even the more toxic compounds can be used safely. Although illnesses and even death from pesticides occur each year in the United States, it should be pointed out that many of these cases are caused by carelessness or by accident. Proper education of workers may prevent some accidents and at the same time, greatly reduce the number of illnesses resulting from carelessness or misuse.

Pesticide Toxicities

In agricultural areas, pesticide usage involves insecticides or miticides, fungicides and herbicides. The more extensively used modern, synthetic insecticide or miticide compounds are the chlorinated hydrocarbons, organic phosphates, and carbamate compounds. The acute toxicity of the organic phosphorus compounds is, on the average, somewhat greater than that of the carbamates or chlorinated hydrocarbons. Because chlorinated hydrocarbons are much more stable than organic phosphorus or carbamate compounds, they can be more of a residue problem.

Exactly how chlorinated hydrocarbons exert their toxic action is not known, but it is known that their primary effect is on the central nervous system. Chlorinated hydrocarbon compounds are fat soluble and tend to accumulate in the body fat of persons exposed to them. Aldrin, dieldrin, and endrin are among the most hazardous compounds in this group of pesticides.

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The symptoms of poisoning by chlorinated hydrocarbons include hyperexcitability, trembling or shaking, and convulsions. General symptoms are a feeling of illness or discomfort, headache, fatigue, and possible lack of appetite and weight loss.

The effect of organophosphorus compounds on the human body is also through the nervous system. However, their specific mechanism of action is understood more completely than is the mode of action of the chlorinated hydrocarbons. The organic phosphorus materials inhibit the enzyme cholinesterase, which functions in the transmission of nerve impulses.

Exposure to the organic phosphorus compounds can be estimated by measurement of cholinesterase activity in the blood. Among the more hazardous organic phosphorus compounds are parathion, TEPP, mevinphos (Phosdrin®), demeton, disulfoton (Di-Syston®), schradan, phorate, and Zinophos®.

The usual signs and symptoms of organic phosphorus poisoning are giddiness, headache, nervousness, weakness, nausea, vomiting, cramps, excessive sweating, and discomfort in the chest. These symptoms are followed or accompanied by blurring of vision; diarrhea; excessive salivation; watering of the eyes; twitching of muscles, especially in the eyelids; and mental confusion. One of the more characteristic signs is constriction of the pupils, which may be preceded by dilation. Late signs are fluid in the chest, convulsions, coma, loss of urinary or bowel control, and respiratory failure.

The antidote in the treatment of organic phosphorus poisoning has been atropine, which acts as an antagonist to the nervous system effects. A more specific antidote, known as 2-PAM, actually breaks down the combination between the enzyme and the organic phosphorus molecule.

The physiologic effect of the carbamate insecticides, as with organic phosphorus compounds, involves inhibition of the enzyme cholinesterase. However, generally speaking, the carbamate-cholinesterase complex is less stable than the organic phosphorus-enzyme combination. Thus, the effects of carbamate exposure tend to be less severe and not so long-lasting as the symptoms that follow organic phosphorus intoxication. Absorption of the carbamates may also be determined by measuring the blood cholinesterase activity. One of the most widely used carbamate compounds is carbaryl (Sevin®).

With the exception of mercury compounds, most common fungicides are less toxic than DDT. Acute poisoning by organic mercury compounds in man is rare in the United States, although such poison-

ings have been reported. However, in other countries there have been many cases of chronic poisoning involving both inorganic and organic mercury. Most chronic cases have been associated with repeated exposure from the manufacturing of organic mercury compounds, from their use in treating seed, or from eating treated seed.

Certain fungicides, particularly ziram, may occasionally cause local irritations or dermatitis. However, these cases are not usually very severe.

Most herbicides are less toxic than other types of pesticides. Two of the most toxic materials commonly used as herbicides are arsenicals and dinitro-type compounds. The arsenical herbicides, although not particularly hazardous to spray men by skin contact, do have a poor safety record. A dinitro compound (dinitrocresol) used for weed control has caused illnesses in Europe.[1] In contrast, tests have indicated that under the conditions of use in the Pacific Northwest area of this country there is no significant hazard associated with the application of dinitro compounds for weed control.[3] This conclusion has been corroborated by use experience.

Precautions to Prevent Pesticide Poisoning

Responsibility for safety precautions in using or handling toxic compounds should rest on all those concerned with pesticide application operations — from management to the worker who actually operates the equipment.

Responsibility of Management: Management should assume responsibility for the supervision of all operations related to the use of pesticides by employees, paying particular attention to acquaint workers with any potential dangers associated with handling toxic compounds.

Regardless of the size of a pesticide application organization or operation, it is wise to arrange for some type of medical supervision, especially if highly toxic chemicals are used. A pre-employment physical examination should include a blood cholinesterase test for employees who may apply the more toxic cholinesterase-inhibiting compounds. This test will provide some indication of normal cholinesterase activity level and may be useful later in determining whether an illness is pesticide poisoning. Personnel working with such compounds, especially the more toxic organophosphorus pesticides, should have their cholinesterase activity checked at regular intervals throughout a work season in order to detect any appreciable deviation from normal which could indicate impending danger of poisoning. If significant reduction in cholinesterase activity is noticed, the employee

should be removed from work situations which might be sources of exposure to pesticides until he is advised by a physician that it is safe to resume his regular duties.

Workers should be supplied with proper protective equipment such as water-repellent clothing and respirators, along with instructions on their proper use and care.

Risk of injury or illness should be minimized by using the best informed and most careful employees in work situations that are potentially hazardous. An applicator should never be allowed to work alone under conditions in which he could not receive prompt help in case of an accident.

Management should also make sure that the least toxic, but most effective, compounds are used. Management should also be sure these compounds are applied at the recommended rate. Application equipment and the application rate should be checked at regular intervals during the season to assure proper dosage and safety.

Protection of the Applicator: Protective clothing and devices should be worn and used as directed during handling, mixing or applying pesticides. Water-repellent clothing provides the best protection. If water-repellent coats or jackets are not required by the pesticide label, or if extremely hot weather makes the wearing of such clothing practically unbearable, the worker should wear at least a washable cloth jacket thick enough to prevent easy penetration by the pesticide. A water-repellent hat with full brim should also be worn to protect the head/face/and/neck area. The commonly-used bill cap has been found to give inadequate protection.

Pesticide applicators should wear water-repellent trousers under conditions of heavy pesticide drift. Rubberized boots should also be worn during practically all types of application.

The best protection for the hands is unlined, rubber, gauntlet gloves. The gauntlet protects the wrist area not normally covered by the sleeve. Since these gloves have no cloth lining, they are also easier to clean.

Always mix pesticides in a well-ventilated area. It is advisable to wear rubberized protective clothing. When mixing or measuring highly toxic organophosphorus compounds, wear goggles to prevent contamination of eyes by concentrate material. If the concentrated form of a toxic pesticide comes in contact with the skin, stop work and wash the contaminated area thoroughly. Remove contaminated clothing and make sure all clothing is thoroughly cleaned before reusing.

If pesticide material does get into the eyes, flush them immediately with flowing water.

Workers should never smoke, chew tobacco, or eat while mixing or applying pesticides. They should wash their hands thoroughly after using pesticides as well as before eating or smoking.

Respirators required during use of pesticide compounds should be approved for the compound in question by the U. S. Department of Agriculture. The filter cartridges should be changed after 8 hours of appreciable exposure, and more often if pesticide odor is detected through the mask. If the filter pads are removable, they should be changed at least once a day. Gas masks with cannister-type filters should be used when high concentrations of toxic vapors are present or when the worker is subjected to prolonged exposure in confined spaces.

Never use the mouth to siphon liquid spray materials or to blow out clogged spray nozzles. Pesticide containers should be opened carefully to avoid splashing liquids and billowing clouds of concentrated dust or wettable powder. When dumping pesticide materials into application equipment, stand so the direction of drift is away from the face. During application, avoid dust or spray drift by starting on the downwind side of the field and apply in cross-drift passes.

During air application the pilot should not take part in the loading operation since the person who loads is often subjected to relatively heavy pesticide exposure.

If a worker does feel ill during pesticide application, or shortly after, he should stop work and seek medical attention at once.

Protection of the Public: In applying pesticides to food plants and crops, use the proper dosage recommended on the label. Allow the prescribed time between applying the pesticide and harvesting the crop. This time will avoid the possibility of a harmful amount of pesticide remaining on food.

Unauthorized persons should not be allowed in the treatment area during pesticide application. When spraying around dwellings, warn the occupants, and particularly children, to stay out of the area, preferably the at least 48 hours, or until the spray has completely dried on foliage, grass, or other sprayed surfaces. Also, make sure that children's toys, containers and other items are removed before spraying. These could retain harmful spray.

If concentrated pesticide is spilled on the ground, remove and

bury the contaminated soil. This precaution is especially important in areas where children may play.

Pesticides should be stored under lock and key to keep them from children or irresponsible persons. Always store pesticides in the original labeled containers. Keep them in a dry, well-ventilated room or building and away from areas where food is stored, handled or eaten. Attach a poison or warning sign to the door. This, too, can help reduce accidents.

Dispose of used pesticide containers so they will not be a hazard to others. Glass, plastic, or metal containers should be thoroughly rinsed with plenty of water as soon as they are emptied. The rinsings can then be poured into the spray tank. This is one of the most important steps in reducing the hazard of such containers. Tests have shown that two thorough rinsings of a 5-gallon parathion drum with water will remove over 95% of the pesticide that normally would be left in the unrinsed drum.[4]

After rinsing, smaller containers should be rendered useless. Glass containers should be broken. Plastic or metal containers should be punctured. This is easily done to smaller cans and drums by use of a conventional hammer with a straight claw. Additional destruction can be accomplished by driving over the containers with a tractor wheel. All used containers should be buried at least 18 inches deep in a carefully selected location to prevent surface or subsurface contamination. If containers are ever taken to a public dump, inform the caretaker so that the containers can be covered as soon as possible.

Disposal or decontamination of large (15 to 55-gallon) drums presents more of a problem. They should be returned to the supplier whenever possible. Certain cooperage firms may be willing to accept empty drums, but check beforehand to find out if the firm is properly equipped to decontaminate them in a safe manner.

If large drums cannot be disposed by the previously described ways they should be thoroughly drained and rinsed with a decontaminating solution of water, detergent, and caustic soda. This method has been recommended by the Subcommittee on Container Disposal of the Grady Committee and was published by the National Agricultural Chemicals Association.[2] They suggest the following solutions: For the 15-gallon size, use 1-1/2 gallons of water, 1/4 cup of detergent, and 1/2 lb. of lye; for the 30-gallon drum, use 3 gallons of water, 1/2 cup of detergent, and 1 lb. of lye; and for the 55-gallon drum, use 5 gallons of water, 1 cup of detergent, and 2 lbs. of lye. Carefully add the rinse solution to the drum and then rotate the container to completely wet all inner surfaces. Let the container stand for at least 15 minutes

with occasional agitation. Remove all bungs or stoppers and drain the rinse into an area where there is no chance of run-off into water supplies. Next, thoroughly flush both the inside and outside of the container with clear water. Although the above procedure may not completely detoxify or remove absolutely all pesticide from drums, it should render them much more safe than they would be without a rinse.

After the decontamination rinse, puncture the bottom of the drums. Bury them in a safe location as described for smaller containers. Drums should not be allowed to accumulate in an area accessible to unauthorized persons who may be tempted to use them for trash-burning containers, livestock water troughs, storage cans, or other purposes.

Combustible containers, such as paper bags and cartons, can be disposed by burning. However, some areas object to this practice because of creating an air pollution problem. If such containers are burned, use extreme caution and avoid the smoke. Empty containers should be burned in a commercial incinerator if available rather than in the field at the pesticide application site. If containers are not burned they should be buried, taking the precautions pointed out above in burying small noncombustible containers.

Another problem that can be a serious hazard to the public is the improper disposal of waste pesticides. Never wash pesticides into a drain, or flush them into a sewage system. The best method of disposal is burial under at least 18 inches of soil in a location carefully selected to insure that no surface or subsurface water will become contaminated. Adding lime or lye is sometimes recommended to speed up the degradation of certain compounds. However, this cannot be relied on to make the buried material completely nontoxic. Neutralizing the poisonous effects of most pesticides is not easy, especially where large quantities of the toxic material are involved. Burning large quantities of pesticide wastes is not advisable because of possible air pollution. Even in especially built incinerators where very high temperatures produce relatively complete combustion, there is no assurance that some toxic smoke or vapor will not be emitted.

What to Do in Case of Pesticide Poisoning

In severe cases of organic phosphorus poisoning, breathing may become labored or even stop. In such a situation, artificial respiration is the most important first-aid treatment. If the skin or clothing is contaminated, remove the clothing and bathe the contaminated skin areas with generous amounts of soap and water. Move the patient to fresh air if poisoning has resulted from exposure to a contaminated atmosphere.

If insecticide has been swallowed and the patient has not vomited, induce vomiting by giving him a tablespoon of salt dissolved in one-half glass of warm water. Do not try to give an unconscious patient anything by mouth. Never induce vomiting when a caustic poison or organic solvent, such as kerosene, has been ingested.

If pesticide material has gotten into the eyes, wash them immediately with flowing water.

Make the patient lie down and keep him warm until a physician arrives or until he can be taken to a hospital. On the way to the hospital, be prepared to give artificial respiration. Provide the physician with information from the pesticide label. Write down a list of ingredients for him or, if possible, give the physician the container which held the suspected poisoning agent.

Do not allow the patient to return to work that involves the source of pesticide exposure until a physician advises the patient it is safe to do so.

In summary, both research and use experience indicate that the very real hazard of certain pesticides requires appropriate precautions on the part of all concerned with application of such compounds. However, approved pesticides can be used safely, if the users follow recommended precautions.

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SAFETY IN THE USE OF PESTICIDES[1]

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Any worker who might become involved in the handling of pesticides should not only be well informed about the effectiveness of various chemicals in control of insects, weeds, fungi, and other pests, but also he should be well acquainted with the potential health hazards involved in the use of these materials. The following information concerning the toxicity of the more widely used pesticides, as well as some suggested precautions to follow when using such compounds, should be helpful to anyone working with pesticides.

The more extensively used of the modern synthetic insecticides are chlorinated hydrocarbon, organic phosphorus, or carbamate compounds. The chemical class to which some of the commonly used pesticides belong is indicated in Table 1. Although there is considerable overlapping in toxicity between these groups, the acute toxicity of the organic phosphorus group is, on the average, somewhat greater than that of the chlorinated hydrocarbon or the carbamate compounds. However, the chlorinated hydrocarbon compounds, due to their greater stability, are considerably more of a residue problem than are the organic phosphorus or carbamate materials.

The exact physiologic mechanism by which the chlorinated hydrocarbon compounds exert their toxic action is not known. However, their primary effect is on the nervous system. The chlorinated hydrocarbons are fat-soluble and tend to accumulate in body fat in animals exposed to them. Lactating animals that have been exposed excrete the chlorinated hydrocarbon materials or their derivatives in milk. Since milk is assumed to be the primary food for infants and invalids, who might be unusually suseptible to the effects of toxicants, the U. S. Food and Drug Administration has not granted a tolerance level higher than zero for residues of any pesticide in milk.

Among the more hazardous of the chlorinated hydrocarbon compounds are aldrin, dieldrin, and endrin. Exposure to the chlorinated hydrocarbons can be established by analysis of body fat and, for certain of these materials such as DDT, by urine tests. By use of the technique of gas chromatography, a test is now available for measuring the chlorinated hydrocarbon pesticides in blood. Preliminary results indicate that the blood test results correlate better with clinical poisoning following exposure than do fat storage or urinary excretion levels.

The organic phosphorus compounds are chemically related to the so-called "nerve gases." Their effect on the human body is also through the nervous system. However, their specific mechanism of action is known more exactly than is the case with the chlorinated hydrocarbons. The organic phosphorus materials inhibit the enzyme cholinesterase, which functions in the transmission of nerve impulses.

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Among the more hazardous of the organic phosphorus compounds are parathion, TEPP, mevinphos (Phosdrin), demeton, di-syston, schradan, phorate, and zinophos.

Exposure to the organic phosphorus compounds can be estimated by measurement of cholinesterase activity in the blood. A urine test is also available for certain organic phosphorus materials, including parathion, EPN, and dicapthon. The antidote of choice in the treatment of organic phosphorus poisoning has been atropine, which acts as an antagonist to the nervous system effects of these compounds. A more specific antidote known as 2-PAM chloride, which actually breaks down the combination between the enzyme and the organic phosphorus molecule, has more recently become available.

The physiologic effect of the carbamate insecticides also involves inhibition of the enzyme cholinesterase. However, generally speaking the carbamate-cholinesterase complex is less stable than is the organic phosphorus-enzyme combination. Thus, the effects of carbamate exposure tend to be less severe and not as long-lasting as the symptoms following organic phosphorus intoxication. Absorption of the carbamates may also be determined by measurement of blood cholinesterase activity. However, due to the above mentioned easy reversibility of the carbamate-cholinesterase combination, special precautions must be taken in analysis to prevent obtaining results which show a higher enzyme activity than is actually present due to reversal of the carbamate-cholinesterase combination during storage or during the test procedure.

The most widely used carbamate pesticide is carbaryl (Sevin). This compound is interesting because it serves the fruit orchardist both as an insecticide and as a thinning agent. Carbaryl is not very toxic mammals; however, bees appear to be very susceptible.

In general, the herbicides and fungicides are less toxic than many of the other types of pesticides. In a survey of the toxicity of 197 pesticides, Edson and his colleagues found that only 4% of the herbicides and 5% of the fungicides fell into the most toxic category (oral LD_{50} to rats: 0-50 mg/kg), while 52% of the organic phosphorus insecticides and 24% of the other insecticides were in this classification.

The LD_{50} values and relative toxicities of some commonly used herbicides are shown in Table 2.

A dinitro-type compound (DNOC) used for weed control has caused illnesses in Europe. Under the conditions of use in this country. however, our tests have indicated that there is no significant hazard associated with the application of dinitro compounds for weed control. This conclusion has been corroborated by use experience.

One of the most widely used herbicides is 2, 4-D. This compound is not very toxic to experimental animals. For comparison, its oral LD_{50} to white rats is about 500 mg/kg as compared to 125 mg/kg for DDT, indicating that 2, 4-D is only about one-fourth as toxic to the rat as DDT. Use experience with 2, 4-D has generally been good from the standpoint of human health. There is a single report of three cases of peripheral neuropathy in persons who had a history of exposure to 2, 4-D. These three cases were all seen in a single hospital during a three-month period.

In cases of extensive respiratory exposure or accidental ingestion of commerical formulations of 2, 4-D herbicides, the aliphatic or aromatic solvents used may cause certain poisoning symptoms characteristic of the solvents but not of 2, 4-D.

The arsenical herbicides deserve special mention. While they are not particularly hazardous by skin contact to the sprayman, the arsenical herbicides have had a poor safety record. For example, in 1956, arsenic compounds were responsible for 54 of the total of 152 deaths (36 percent) caused by pesticides in that year in the United States.

The LD50 values and relative toxicities of some of the commonly used fungicides are cited in Table 3.

With the exception of the mercury compounds, the common fungicides listed are all less toxic than DDT. Acute poisoning by organic mercury compounds has been reported infrequently in man, although such poisoning has occurred. However, there have been many cases of chronic poisoning involving both inorganic and organic mercury. Most chronic cases were associated with repeated exposure in connection with the manufacture of organic mercury compounds, their use for treating seed, or the eating of treated seed. Other cases were associated with the ingestion of seafood contaminated by industrial waste.

Certain fungicides, including particularly ziram, may occasionally cause local irritations or dermatitis; however, these cases are usually not very severe.

In Table 1 are summarized the estimated relative acute toxic hazards of some of the more common pesticides to spraymen. It should be emphasized that this table is based primarily on toxicological data from experimental animals although use experience, where available, is also considered. The classifications are both approximate and relative. The safe use of those compounds listed in the "Most Dangerous" category requires full attention to all recommended precautions. Those materials in the less hazardous categories may be safely used with correspondingly less protective clothing and equipment. The more toxic materials easily enter the body through contact with the skin as well as through breathing. Ingestion of any of these compounds may be fatal.

Here are Some Suggested Precautions to Follow when Using Pesticides:

1. If you are in the pesticide application business make sure your physician knows the types of compounds you are using. If you anticipate using the more toxic organic phosphorus materials, he may suggest that you have a preseason blood test to determine your normal cholinesterase activity level. He will then be in a better position to deal with a sudden illness. If he should provide you with a supply of atropine tablets for organic phosphorus poisoning do not take them before definite symptoms occur. If you ever take atropine tablets, call your physician as soon afterward as possible. Any person who is ill enough to receive a single dose of atropine should be kept under medical observation for 24 hours, because atropine may produce only temporary relief of symptoms in what may prove to be a serious case of poisoning. Keep atropine tablets away from children.

2. Be sure those who work with you are aware of the hazard involved when using toxic pesticides.

3. Wear protective clothing (preferably water-repellent) while spraying hazardous materials as toxic pesticides can be absorbed into the body through the skin. Change and launder clothing and bathe daily.

4. Wear a respirator mask when loading or mixing wettable powders or when applying dusts. The respirator should be approved for the material in question by the U. S. Department of Agriculture. An approved respirator should be worn whenever the more volatile of the toxic compounds are being used, expecially TEPP and mevinphos (Phosdrin). The filters and pads should be changed at regular intervals.

5. Never measure or leave mixtures of insecticides in beverage bottles or in labeled cans or boxes which have formerly contained food products. Burn or bury empty insecticide bags or other containers. Each year tragic, preventable poisonings occur when children obtain food containers filled with insecticide or get hold of "empty" insecticide containers.

6. Bear in mind that a little extra water-rinsing of a container for liquid pesticide may make the difference between leaving a hazardous container, and leaving one in which it would be difficult for children to find enough toxic pesticide to cause much harm. It may be the life of your child you are saving.

7. Keep your pesticide storage shed or room locked.

8. Do not smoke chew tobacco, or eat whild spraying or while your hands are contaminated, especially with concentrate materials.

9. Mix pesticides according to directions and apply at the recommended rate. Use the least toxic compound that will do the job well. This is especially important in urban areas where sprays are applied near dwellings.

10. When spraying near dwellings make sure you have not left puddles of spray on hard soil surfaces. Also check children's playthings, such as mud pie dishes, or other containers that may retain the spray solution and endanger small children who may enter the yard later.

11. When spraying around dwellings warn the occupants to keep children out of the treated area, preferably for a period of 48 hours. Under no conditions should they enter the area until the spray has completely dried on the foliage, grass or other sprayed surface.

12. If concentrated pesticide is spilled on the ground remove or bury the contaminated soil. This is especially important in areas where small children play. Certain pesticides are known to have retained high toxic concentrations in the soil for a period of over six months, and at least one child was seriously poisoned by placing such contaminated soil in the mouth.

Watch for These Symptoms:

Most pesticides easily enter the body through contact with skin, as well as through the mouth and throat and through breathing. Repeated exposures to such compounds may increase susceptibility to poisoning even though no immediate symptoms are produced. The initial symptoms of organic phosphorus

poisoning are giddiness, headache, nausea, vomiting, excessive sweating, and tightness of the chest. These are followed by, or accompanied by, blurring of vision, diarrhea, excessive salivation, watering of the eyes, twitching of muscles, especially in the eyelids, and mental confusion. One of the most characteristic signs is constriction of the pupils, but this may be preceded by dilation. Late signs are fluid in the chest, convulsions, coma, loss of urinary or bowel control, and respiratory failure.

The symptoms of poisoning by the chlorinated hydrocarbon insecticides, such as dieldrin and endrin, are primarily due to their effect on the nervous system and include hyperexcitability, trembling or shaking and convulsions. General symptoms are a feeling of illness or discomfort, headache, fatigue, and possible lack of appetite and weight loss.

What to Do for Poisoning:

1. In severe cases of organic phosphorus poisoning, breathing may stop. In such a situation artificial respiration is the most important first aid until breathing has resumed.

2. Get the patient to a hospital or physician as soon as possible. Give artificial respiration on the way if the patient turns blue or stops breathing. If you know which pesticide may be involved, take along a label for the doctor's information. If the label does not remove easily take along the entire pesticide containter.

3. Never try to give anything by mouth to an unconscious patient.

4. INTERNAL-- If the insecticide has been swallowed and the patient has not vomited, induce vomiting by giving a tablespoonful of salt dissolved in one-half glass of warm water.

5. SKIN-- Where the insecticide has come into contact with the skin, immediately remove all clothing and bathe the patient with generous amounts of soap and water, rinsing thoroughly.

6. EYES-- If spray, especially insecticide concentrate, gets into the eyes, wash them immediately with flowing water.

7. Make the patient lie down and keep him warm.

In summary, both research and use experience with pesticides indicate that the very real hazard of certain pesticidal compounds requires appropriate precautions on the part of those using them but that approved pesticides can be used safely provided recommended precautions are followed. Thus, it is of primary importance to read and follow the precautions on the label.

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Table 1: Estimated Relative Acute Toxic Hazard of Pesticides to Spraymen[1]

Most Dangerous	Dangerous	Less Dangerous[2]	Least Dangerous
Demeton (Systox) (OP)[3]	Aldrin (CH)	BHC (CH)	Aramite (M)
Di Syston (OP)	Bidrin (OP)	Binapacryl (Morocide) (N)	Captan (M)
Mevinphos (Phosdrin) (OP)	Carbophenothion (Trithion) (OP)	Chlordane (CH)	Carbaryl (Sevin) (C)
Parathion (OP)	DDVP (OP)	Co-Ral (OP)	Chlorobenzilate (CH)
Schradan (OMPA) (OP)	Delnav (OP)	Diazinon (OP)	2,4-D (CH)
TEPP (OP)	Dieldrin (CH)	Dicapthon (OP)	Diquat (M)
Phorate (Thimet) (OP)	DNOC (N)	Dichloroethyl Ether (M)	DDD (TDE) (CH)
Zinophos (Cynem) (OP)	DNOSBP (N)	Dimethoate (OP)	DDT (CH)
	Endrin (CH)	Dipterex (Dylox) (OP)	Dilan (CH, N)
	EPN (OP)	Endosulfan(Thiodan)(CH)	2,4,5-T (CH)
	Ethion (OP)	Fenthion (Baytex) (OP)	IPC (M)
	Methyl Demeton (Meta-Systox) (OP)	Guthion (OP)	Karathane (N)
	Methyl Parathion (OP)	Heptachlor (CH)	Kelthane (CH)
	Nicotine (M)	Lead Arsenate (M)	Malathion (OP)
	Pentachlorophenol (M)	Lindane (CH)	Maneb (M)
	Phosphamidon (OP)	Naled (Dibrom) (OP)	Methoxychlor (CH)
	Sodium arsenite (M)	Ruelene (OP)	Mirex (CH)
	Zectran (C)	Toxaphene (CH)	Morestan (M)
		VC-13 (OP)	NAA (M)
		Vapam (M)	Perthane (CH)
			Phostex (OP)
			Piperonyl Butoxide (M)
			Ronnel (Korlan) (OP)
			Rotenone (M)
			Simazine (M)
			Sulphenone (M)
			Tetradifon (Tedion) (CH)
			Thiram (M)
			Zineb (M)
			Ziram (M)

[1]The estimates of hazard in this table are based primarily on the observed acute dermal and to a less extent oral toxicity of these compounds to experimental animals. Where it is available, use experience has also been considered. It should be noted that the classification into toxicity groups is both approximate and relative.

[2]The fumigant compounds acrylonitrile, D-D, and Telone have systemic toxicities which would indicate their placement in the "Less Dangerous" category. However, special note should be taken of the fact that the volatility of these compounds and their capacity to produce irritation of skin, eyes, and other tissues indicate that appropriate caution should be exercised in their use.

[3]The chemical class to which the pesticide belongs is designated as follows: C, carbamate; CH, chlorinated hydrocarbon M, miscellaneous; N, nitro, and OP, organic phosphorus.

Table 2: Toxicity of Herbicides

Chemical	LD_{50} Value to White Rats[1] (mg/kg)	Relative Toxicity[2]
2, 4-D	400-500	0. 36
2, 4, 5-T	300-800	0. 23
Diquat	400-440	0. 30
DNOC	25-40	3. 85
IPC	1000-9000	0. 03
Simazine	5000	0. 03
Sodium arsenite	70	1. 78
DDT	125	1. 00

Table 3: Toxicity of Fungicides

Chemical	LD_{50} Value to White Rats[1] (mg /kg)	Relative Toxicity[2]
Captan	9000-15, 000	0. 01
Ceresan (mercurial)	30	3. 12
Dodine	1000-2000	0. 08
Karathane (dinocap)	980-1190	0. 11
Maneb	7500	0. 02
Sulfur	non-toxic	----
Pentachlorophenol	280	0. 45
Thiram	375-865	0. 20
Zineb	5200	0. 02
Ziram	1400	0. 09
DDT	125	1. 00

[1]The LD_{50} value refers to the amount of a substance which would theoretically kill 50 percent of the animals tested. The lower figures are associated with substances of higher toxicity.

[2]The values refer to the relative toxicity of these chemicals based on DDT as 1. 00. The substances with relative toxicity values greater than 1 are more toxic than DDT while those compounds with relative toxicity less than 1 are less toxic than DDT.

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SAFE HANDLING OF PESTICIDES IN FOREST AND RANGE LAND AREAS

The pesticides which have seen most widespread use in forest and range areas have been compounds of relatively low acute toxicity and have not caused many health hazard problems for persons who come in contact with the materials. The greatest potential hazard to workers has probably occurred during handling of the concentrate forms of the few more toxic compounds used. Even though there is an effort to insure that pesticides produced and used in the future will be low in toxicity to warm-blooded animals and not persistent in the environment, there is no assurance that all compounds finding use in forest and range areas will be of low acute toxicity. Thus, we should not lessen our concern about the hazard to persons who come in contact with such compounds. Protection from exposure is necessary if a good record for safe use and handling of pesticides is to be maintained.

Although the hazard is greater when working with compounds of higher toxicity, it should be noted that many of the less toxic compounds can present some need for concern under conditions of gross misuse, accident, or carelessness and it is a wise practice to take precautionary measures to avoid excessive exposure. For example, malathion, while not a compound of high systemic toxicity, has been shown to be a skin sensitizing agent and a potential cause of dermatitis in exposed individuals (Milby and Epstein, 1964). The acute hazard during application of certain chlorinated hydrocarbon pesticides is comparatively low. However, these compounds are stored in body fat following absorption, and their presence in the body is sustained over a longer period of time. Although most of the newer herbicides are considered relatively safe as far as the applicator is concerned, it is advisable to avoid exposure because of the limited use experience with many of the compounds to date.

Much of the safety in relation to pesticides rests not only on the foreman and other supervisory personnel but on the worker who actually applies the materials. If he is knowledgeable concerning pesticides and understands the importance of taking proper precautions he can do much to insure the safety of himself and others. He can also prevent excessive

contamination of the general environment. Thus, an important adjunct to safety in relation to pesticides is education of those persons who actually handle the materials.

There are several important indirect ways of protecting the worker such as providing education and medical supervision, stressing the importance of personal hygiene and cleanliness, emphasizing the importance of not being careless, and pointing out the need for reading and following directions on the pesticide label. However, direct protection of workers from absorption of pesticides through the routes of entry into the body is exceptionally important.

There are three main routes of entry of pesticide compounds into the body: (1) dermal, (2) respiratory, and (3) oral. The dermal route has been determined to be the most important route of entry into the body in field studies of pesticide applications (Wolfe *et al.*, 1967). For example, during most exposure situations studied, over 97 percent of pesticide contamination of the entire body was deposited on the skin. Although any given amount of pesticide is more rapidly and more completely absorbed by the oral or respiratory routes, the disproportionate amount of contamination that can occur on the skin indicates the importance of wearing proper protective clothing.

The insidiousness of absorption by the dermal route adds to its hazard. Most persons are aware of the danger of swallowing or breathing insecticides, but the possibility of absorbing appreciable amounts of a poison through the intact skin is not so familiar.

Although much of the treatment of forest lands is by aerial application, ground equipment is also occasionally used. Whenever individual forest tree treatments are made by ground crews using power equipment and hand nozzles, there is opportunity for significant exposure from drift and dripping onto the workers, especially if trees are large enough to require directing the spray upward above the level of the head. This often thoroughly wets the protective or conventional clothing being worn and may result in gross contamination of exposed skin surfaces.

The warning statement on practically all pesticide labels indicates that prolonged skin contact should be avoided, and labels of the more toxic compounds even spell out certain specific articles of protective clothing that should be worn. Many different kinds of protective clothing are being used, and we have been attempting to evaluate some of them. Most people visualize that the ideally protected sprayman is covered from head to foot with heavy black rubberized waterproof clothing – the sou'wester hat, jacket, trousers, gloves, and boots in addition to a respirator and perhaps goggles. This type protection is advisable under conditions of exposure to some highly toxic pesticides even though there is much discomfort and poor acceptance as far as the worker is concerned.

The only skin area exposed under these circumstances is the face-neck area, and the brim of the hat provides some protection for that area. This type protective clothing is often worn during cooler conditions. However, as the temperature rises and these articles become unbearably hot to wear, the workers tend to take them off and work with less protection.

Several types or grades of lightweight water-repellent protective clothing are now available for the sprayman. These are much more comfortable and acceptable than the heavier rubberized clothing. The newer items are made of thinner synthetic materials. Although they will probably wear out or deteriorate more rapidly than will the heavy grade rubber clothing, they provide good protection. Workers find this lighter clothing more acceptable during hot weather. When workers are lax in the use of protective gear – for example, during application of compounds of low toxicity or during extremely hot weather when waterproof protective clothing is difficult to tolerate – workers should be encouraged to at least wear washable cloth jackets that will not readily absorb moisture. Many spraymen wear heavy grade long-sleeved cotton shirts or coveralls, often with no underclothing. These items of outer clothing provide a reasonable amount of protection where spray drift is light and the droplets are so small that they do not accumulate fast enough to penetrate through to the skin. Under such conditions the clothing should be changed and laundered daily. If spray clothing is merely hung up to dry after work and used repeatedly, pesticide material will eventually accumulate enough to contaminate underclothing and skin.

For head protection during warm weather a bill cap is commonly used. This item is popular because respirator straps can be easily adjusted over the outside of the cap. Although this type of headgear provides some protection for the face, it gives practically no protection for the rest of the face-neck area. It is not advisable to wear any type of cloth headgear which might easily become saturated with spray. A water-repellent hat with full brim provides some protection for all the face-neck area and is not particularly uncomfortable to wear. Plastic or metal "hard-hats" are acceptable if they have full brims. However, "hard-hats" which allow circulation of air over the head under the hat should not be used where exposure is to toxic dusts.

One question often raised relates to the protection afforded by gloves during pesticide application operations, since they easily become contaminated on the inside. Cloth-lined rubberized gloves, although more comfortable than unlined gloves, become more contaminated on the inside than do the unlined gloves and are more difficult to clean. However, spraymen wearing gloves of either type receive less contamination on the average than do those working without gloves. For example, in a series of

tests using dinitro compounds, spraymen received an average of 22.4 mg/hr contamination of hands when wearing gloves that were contaminated on the inside. When they worked without gloves the value rose to 91.1 mg/hr (Wolfe *et al.*, 1961). If gloves are never removed there should be no problem of contamination on the inside; however, rare is the worker who does not remove his gloves to smoke, to adjust the spray machine engine, or even to tear open a bag of pesticide.

It is important to secure the correct grade of gloves. Those which provide the most protection are the gauntlet type. The gauntlet gives protection to the wrist area not covered normally by the sleeve. Gloves of various grades or thickness are now available. Heavy, nonflexible gloves interfere with movement of the hands. On the other hand, if gloves are very thin and pliable, they may tear or wear out easily and become uncomfortable from perspiration on the inside during hot weather. Natural rubber gloves are recommended when working with highly toxic organophosphorus compounds because they deteriorate more slowly, resulting in less chance of penetration by the toxic material.

As far as other articles of protective clothing are concerned, it is advisable to wear rubberized trousers under conditions of heavy pesticide drift. Rubberized boots should be worn during practically any type of application. Usually the ground cover becomes thoroughly contaminated and leather boots or shoes become soaked and deteriorate under repeated use allowing penetration of pesticides.

It is particularly important to avoid spillage of concentrated forms of pesticide onto the skin. One small spillage of concentrate, if not promptly removed, might result in more absorption than a worker would receive over a period of several days of normal spraying with the dilute formulation. Any such spillage should be thoroughly washed off with soap and water. In the case of the more highly toxic compounds, this should be done immediately. A bar of soap, a towel, and an extra canteen of water should be carried on every supply truck and spray machine for this purpose. Provision of these items in forest spray activities is of particular importance since normal washing facilities may be distant.

At the end of spraying activity for the day, it is important that each worker bathe thoroughly to remove any pesticide which has been deposited on the skin and thus preclude further absorption.

The above considerations apply to the dermal route of exposure – the one of primary importance for spraymen. However, attention should also be given to protection from respiratory and oral exposure.

Protection of the respiratory route of exposure is especially important where toxic dusts and vapors or very small spray droplets are prevalent. Respiratory exposure is greater during applications using fogging or

aerosol-type equipment because the droplets formed are much smaller than those produced by many conventional spray machines. Certain concentrate spray machine nozzles also produce relatively small droplets. Tests have shown that when operating an 8X (8 times normal concentration) concentrate airblast machine, the potential respiratory exposure is nearly three times greater than when operating a conventional dilute spray machine (Wolfe *et al.*, 1966).

Respiratory protection can be provided by use of gas masks or respirators. The gas mask is more effective but also more uncomfortable to wear than the respirator. Gas masks should be used when high concentrations of toxic vapors are present or when there is prolonged exposure in confined spaces with no ventilation. The more commonly used respirators are the half-face mask with one or two cartridges attached which contain activated charcoal as an adsorbing material. Most respirators have filter pads over the cartridge units. Applicator pilots who risk the possibility of flying through drift of fine droplets or dusts should consider the use of some type of face mask equipped with a filter cannister attached either to their belt or to the inside of the cockpit.

Proper care of respirators is very important. The rubber facepiece becomes hardened, and the head straps lose their elasticity with age and exposure to heat and sunlight. These conditions lead to poor fit and allow leakage around the facepiece. Two of the more common offenses in the care of respirators are failing to wash the facepiece with soap and water and neglecting to change the filter cartridges regularly. Washing of the facepiece should not be attempted while the cartridges are in place as moisture may contact the activated charcoal filter material and reduce its effectiveness in adsorption of pesticide. Solvents should not be used for they may damage certain parts of the respirator. The general recommendation is that cartridges should be changed after 8 hours of continuous exposure. Under conditions of intense exposure the useful life of the cartridge is shorter. Thus, if breathing seems hampered, or if the odor of pesticide is detected, the filter cartridges should be changed immediately. If the filter pads are a separate removable unit, they should be changed more frequently than the cartridges.

Oral contamination may be brought about by drift of pesticide onto the lips or mouth area, by contamination of food items, or by careless actions such as attempting to blow out clogged spray nozzles with the mouth. A certain amount of oral contamination may also occur from smoking contaminated cigarettes. However, cigarette contamination is usually considered to be more closely associated with respiratory exposure. Although oral exposure is considered to be a minor occupational problem for pesticide spraymen, there has actually been little experimental

work done to define its magnitude. Adequate techniques for studies of this sort do not seem to be available. However, in limited studies designed to measure potential exposure associated with handling cigarettes or food with contaminated hands, our laboratory analyzed such items after handling by spraymen and fruit thinners. When smoking or handling cigarettes with contaminated dry hands, the content of endrin, parathion, or azinphosmethyl was found to be not more than 4 micrograms per cigarette in situations involving dilute spray. Higher levels of pesticide contamination (20 to 50 micrograms per cigarette) occurred rarely and only with spray-moist hands that were wet enough to leave moist spots on the cigarette paper (Wolfe *et al.*, 1963; Wolfe, H. R., unpublished data). Contamination of sandwiches by thinners working in parathion residue was also very low. Obviously, greater hand contamination and correspondingly increased potential oral exposure could result from contact with the more concentrated pesticide formulations such as are encountered during mixing and loading.

The safety responsibilities of pesticide applicators go beyond the actual spraying and dusting operations. Contamination of water and soil should be avoided -- for example, tanks for ground spraying should never be filled from streams. Even if an operation is some distance from a stream, tank run-over or spillage on the ground may eventually contaminate the stream through run-off during heavy rain or by particles of contaminated soil which may be carried to the stream by wind during dry conditions. If concentrated pesticide should be spilled on the soil, especially the emulsifiable form of any of the more toxic compounds, the contaminated soil should be dug up and buried in a safe location where there will be no contamination of water through seepage or surface run-off.

Special precautions to avoid spillage should be taken around picnic areas, camp sites, or other places where small children are likely to play. This is emphasized by the fact that over half of the deaths each year due to pesticides involve children (Hayes, 1960). One severe but nonfatal case involved a 2-year-old boy who nearly died from parathion poisoning after ingesting dirt from the driveway of his home (Quinby and Clappison, 1961). The contamination had occurred over 6 months previously when parathion concentrate leaked or spilled from a truck. At the point where the child had been digging, the soil was analyzed and found to contain almost 1 percent parathion.

Empty containers should never be discarded in forest or range areas or left in any place where they might be a hazard to children, pets, wildlife, livestock, or to adults who may convert them to other uses – for example, in forest areas campers may use discarded containers for water, cooking, etc. Metal drums should always be thoroughly rinsed with plenty of water

as soon as they are emptied. In this way the rinsings can be poured into the spray tank. Tests at this laboratory have shown that two thorough rinsings of a 5-gallon "empty" parathion drum with water will remove over 95 percent of the pesticide left in the unrinsed drum. After drums are emptied they should be punctured to make them unusable. This is easily done using a conventional hammer with a straight claw. In addition to puncturing the drums, it is advisable to crush them and bury them at least 18-inches deep in an isolated location away from water supplies. If containers are ever taken to a public dump, the caretaker should be informed so that they can be covered over as soon as possible.

In all types of pest control operations the integrity of stored supplies of the chemicals must be assured. All pesticides should be stored in a locked building or room where no food items are stored. Pesticides should never be stored in beverage bottles or in other small containers which have formerly contained food products. Each year tragic preventable poisonings occur when children have access to such containers filled with toxic materials. Storage should be in a dry place in the original, labeled containers and with the labels plainly visible. Herbicides should be kept apart from other pesticides to avoid cross-contamination and substitution errors. All lids and bungs should be tight and containers should be periodically checked for corrosion, leaks or breaks so that faulty containers may be detected and removed before they become a hazard. Avoid stacking pesticide drums and bags too high since the combined weight may break the packages or cause leaks of drums on the bottom. Glass containers of chemicals should not be stored in direct sunlight where heat rays from the sun may be concentrated and result in fire. The outside of storage sheds or warehouses should be plainly labeled with the words "Danger" and/or "Poison" along with the familiar skull and crossbones and the words "Pesticide Storage."

As noted above, if recommended safety precautions are followed, no health problem should result from pesticide usage. However, in case of any illness suspected to be caused by pesticides, the patient should be taken to a physician as soon as possible. A label should be taken along to provide information on the compound involved. If the label does not remove easily the entire container should be carried. If the illness is diagnosed as having been caused by a pesticide he should not return to work until a physician advises that it is safe to do so.

In summary, workers must become well informed concerning the hazards involved in the use of pesticides if these chemicals are to be used safely. Information on the pesticide label represents the results of research and legislation in the interest of safety to the user and the general public. However, it is the individual user who must take personal responsibility to

read the label and follow the directions. If this is not done, some hazards may exist, accidents and illnesses may occur, and there may be excessive contamination of the environment.

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SAFE USE OF PESTICIDES BY MOSQUITO CONTROL WORKERS

PESTICIDE PUBLICATION 553

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The insecticides which have been of primary importance in mosquito control activities over the years are members of either the chlorinated hydrocarbon or the organophosphorus groups; however, carbamate compounds have also been used to some extent. Although there is considerable overlapping in toxicity among these groups, the acute toxicity of the organophosphorus group is, on the average, somewhat greater than that of the chlorinated hydrocarbons or carbamates. Because some of the compounds are relatively toxic, workers handling or applying pesticides should be well acquainted with the potential health hazards involved in the use of these materials.

Because of concern over the possible hazardous effect of chlorinated hydrocarbons on the environment these compounds are little used in vector control at the present time. Such compounds, due to their greater stability, are considerably more of a residue problem than are the organophosphorus or carbamate materials. They are also fat soluble and tend to accumulate in body fat in animals exposed to them. The exact physiologic mechanism by which the chlorinated hydrocarbon compounds exert their toxic action is not known. However, their primary effect is on the nervous system. The chlorinated hydrocarbon most widely used for mosquito control in the past has been DDT.

The effect of organophosphorus compounds is also through the nervous system. However, their specific mechanism of action is known more exactly than is the case with the chlorinated hydrocarbons. The organophosphorus materials inhibit the enzyme cholinesterase, which functions in the transmission of nerve impulses. Exposure to such compounds can be estimated by measurement of cholinesterase activity in the blood. The antidote of choice in the treatment of organophosphorus poisoning has been atropine, which acts as an antagonist to the nervous system effects of these compounds. A more specific antidote known as 2-PAM (pralidoxime chloride) which actually breaks down the combination between the enzyme and the organophosphorus molecule is also available. Fenthion (Baytex), parathion, methyl parathion, Dursban, Abate, and malathion are among the pesticides in the organophosphorus group finding use in mosquito control operations.

The physiolcgic effect of the carbamate insecticides also involves inhibition of the enzyme cholinesterase. However, generally speaking, the carbamate-cholinesterase complex is less stable than is the organophosphorus-enzyme combination. Thus, the effects of carbamate exposure tend to be less severe and not as long-lasting as the symptoms following organophosphorus intoxication. Absorption of the carbamates may also be determined by measurement of blood cholinesterase activity. However, due to the above mentioned easy reversibility of the carbamate-cholinesterase combination, special precautions must be taken in analysis to prevent obtaining results which show a higher enzyme activity than is actually present due to reversal of the carbamate-cholinesterase combination during shipment, storage, or the test procedure. The antidote of choice for carbamate poisoning is atropine. The use of 2-PAM is contraindicated. Baygon and carbaryl are examples of carbamate compounds that have been used for mosquito control.

The acute oral and dermal LD_{50} values[1] of certain pesticides that have been used for mosquito control are shown in the table below:

Toxicity of Selected Pesticides to White Rats[a]

Compound	Chemical Class[b]	Oral LD_{50}		Dermal LD_{50}	
		Male	Female	Male	Female
Parathion	OP	13	3.6	21	6.8
Methyl parathion	OP	14	24	67	67
Dichlorvos	OP	80	56	107	75
Baygon	C	83	86	>2400	>2400
DDT	CH	113	118	----	2510
Dursban	OP	155	82	202	----
Fenthion	OP	215	245	330	330
Carbaryl	C	850	500	>4000	>4000
Malathion	OP	1375	1000	>4444	>4444
Abate	OP	8600	13,000	>4000	>4000

[a]The LD_{50} value refers to the amount of a substance which would theoretically kill 50% of the animals tested. The lower figures are associated with substances of higher toxicity.

[b]OP--organophosphorus compound
C--carbamate compound
CH--chlorinated hydrocarbon compound

As far as hazard to workers who handle and apply pesticides is concerned, the dermal toxicity is a more meaningful figure than the oral toxicity. This is because the dermal route of entry into the body is more important during most exposure situations encountered in mosquito control operations.

There are several important indirect ways of protecting the worker such as providing medical supervision, stressing the importance of personal hygiene and cleanliness, the importance of not being careless, and pointing out the need for reading and following directions on the pesticide label. Medical supervision should include regular tests for blood cholinesterase level (1) prior to start of work season, and (2) at least every two weeks thereafter during the work season if exposure is to cholinesterase-depleting compounds.

Direct protection of the various routes of entry of pesticide compounds into the body as a means of preventing exposure is also very important. There are four routes of entry: (1) dermal, (2) respiratory, (3) oral, and (4) through cuts or abrasions in the skin.

Dermal Route

Dermal absorption of pesticides by workers exposed during mosquito control operations is especially important where liquid sprays are involved or when dispersing granular material by hand when not wearing gloves. Protection is afforded by use of various items of clothing preferably waterproof. In selecting protective clothing, it is important to take into consideration the comfort of the worker when he wears such items. The conventional dark-colored, rubberized, or

plastic waterproof jackets and gloves in common use during past years are considered by many applicators to be uncomfortable to wear, not only because of greater heat absorption, but also because they may be of heavy grade material and not very flexible. During recent years, however, items made of materials that are lighter in color and weight have been available. Although less durable, they are less costly to replace.

Respiratory Route

Protection of the respiratory route is especially important where dusts, vapors, fogs, or any application involving very small particles or droplets are concerned. A face mask cartridge-type respirator should be worn during mosquito control operations, if it is apparent that fine droplets or particles are reaching the face area.

Oral Route

The most serious oral exposure may be brought about by splashing of liquid concentrate into the mouth while pouring and measuring pesticides. Contamination may also occur through licking the lips, by rubbing the mouth with contaminated arms or hands, by careless actions such as attempting to blow out clogged spray nozzles with the mouth, or by eating or drinking with contaminated hands.

Entry Through Cuts or Abrasions

Any break in the skin may allow a more direct route of entry into the blood stream. Cuts and abrasions occur most frequently on the hands, and, unfortunately, the hands are the body area most often in contact with the more concentrated forms of pesticides. The difficulty of properly dispersing granular pesticides by hand when wearing most any type of glove is recognized. However, workers with scratches or cuts on the hands should be required to either wear gloves or not be allowed to disperse the material by hand.

DISCUSSION

To my knowledge the record of safe use of pesticides in mosquito control operations in the Pacific Northwest has been very good. During the last few years, we have conducted a limited number of studies to determine the potential dermal and respiratory exposure of workers to certain compounds. The results indicate that in most cases, the workers are subjected to only a relatively low percentage of a toxic dose per hour of exposure during application operations. We have also analyzed blood samples for cholinesterase activity in a number of workers from several abatement districts. The cholinesterase levels found indicate no important effect of exposure to most compounds. However, during the latter part of the work season the values for a few individuals were found to be lowered to the point that warranted advising the individuals to take more precautions in protecting themselves. Illnesses suspected of being due to pesticide exposure have been rare in mosquito control workers.

A large portion of the blood samples analyzed at our laboratory during recent years were from workers exposed to fenthion, malathion, or Dursban. We have had inquiries concerning the importance of the progressive lowering of plasma cholinesterase while the RBC values remain at or near normal following exposure to Dursban. This may also occur to some extent when exposure is to fenthion, but it seems to be much more pronounced when exposure is to Dursban.

With appreciable reduction of red cell cholinesterase activity poisoning symptoms may appear; however, the effect of low plasma cholinesterase is not clear. If poisoning symptoms have appeared in association with a low plasma value alone, it has not been recorded in the literature. In a study of mosquito control workers applying Dursban, Eliason et al.[2] found more than 50% reduction of plasma cholinesterase values within two weeks after exposure started. In fact, there was over 90% decrease in plasma enzyme level of one individual as compared to his pre-exposure level. No inhibition of red cell cholinesterase activity was observed at any time and no clinical manifestations of organophosphorus poisoning were noted in any of the spraymen. Nevertheless, an appreciable reduction of plasma cholinesterase warrants some concern about the worker's exposure even though his RBC value is in the normal range. He should be observed to determine if he appears to be subjecting himself to excess amounts of pesticide and advised to take better precautions to protect himself from exposure.

Regardless of how specifically the measures for protection of workers from exposure to the more toxic pesticides used in mosquito control may be stated for any particular situation, people who work with such compounds must realize that there is some element of risk involved. Accidents occur, even among workers who are careful. In case of accidental gross contamination of skin with a toxic compound, especially liquid concentrate, every effort should be made to cleanse the contaminated area as quickly as possible. The best recommendation, at present, is the use of plenty of soap and water. A bar of soap, towel, and container of water should be carried on every pesticide application machine or accompanying vehicle for use in washing should a spillage occur. If pesticide gets in the eyes, they should be thoroughly flushed with water for several minutes. If a person should feel ill while working with pesticides, he should stop work at once and get medical attention. If his illness is diagnosed as being caused by a pesticide, he should not be allowed to return to work until a physician advises that it is safe to do so.

Even though a few of the pesticides currently used for mosquito control are comparatively toxic, our research has indicated that workers are generally exposed to relatively small fractions of a toxic dose each day. These findings are consistent with the idea that pesticides can be used safely, provided recommended precautions are followed. However, excess exposure due to accident or lapses in adherence to safety precautions might be sufficient to allow poisoning to occur.

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